State of New York—Department of Agriculture

Twenty-Second Annual Report

of the

BOARD OF CONTROL

of the

NEW YORK
Agricultural Experiment Station

(GENEVA, ONTARIO COUNTY)

FOR THE YEAR 1903

With Reports of Director and Other Officers

TRANSMITTED TO THE LEGISLATURE JANUARY 15, 1904

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1904

STATE OF NEW YORK.

No. 30.

IN ASSEMBLY,

JANUARY 15, 1904.

TWENTY-SECOND ANNUAL REPORT

OF THE

Board of Control of the New York Agricultural Experiment Station

STATE OF NEW YORK:

DEPARTMENT OF AGRICULTURE,

ALBANY, *January* 15, 1904.

To the Assembly of the State of New York:

I have the honor to herewith submit the Twenty-second Annual Report of the Director and Board of Managers of the New York Agricultural Experiment Station at Geneva, N. Y., in pursuance of the provisions of the Agricultural Law.

I am, respectfully yours,

CHARLES A. WIETING,

Commissioner of Agriculture.

NEW YORK AGRICULTURAL EXPERIMENT STATION,

W. H. JORDAN, *Director.*

GENEVA, N. Y., *January* 15, 1904.

Hon. CHARLES A. WIETING, *Commissioner of Agriculture, Albany, N. Y.:*

DEAR SIR.—I have the honor to transmit herewith the report of the Director of the New York Agricultural Experiment Station for the year 1903.

Yours respectfully,

S. H. HAMMOND,

President Board of Control.

1903.

ORGANIZATION OF THE STATION.

BOARD OF CONTROL.

Governor Benjamin B. Odell, Jr., Albany.
Stephen H. Hammond, Geneva.
Frederick C. Schraub, Lowville.
Lyman P. Haviland, Camden.
Edgar G. Dusenbury, Portville.
Jens Jensen, Binghamton.
Thomas B. Wilson, Halls Corners.
Milo H. Olin, Perry.
Irving Rouse, Rochester.
Charles W. Ward, Queens.

OFFICERS OF THE BOARD.

Stephen H. Hammond,
President.

William O'Hanlon,
Secretary and Treasurer.

EXECUTIVE COMMITTEE.

Stephen H. Hammond,
Frederick C. Schraub,
Lyman P. Haviland,
——— ———.
Thomas B. Wilson.

STATION STAFF.

Whitman H. Jordan, Sc. D., *Director.*

George W. Churchill,
Agriculturist and Superintendent of Labor.

William P. Wheeler,
First Assistant (Animal Industry).

Fred C. Stewart, M. S.,
Botanist.

Harry J. Eustace, B. S.,
Assistant Botanist.

Lucius L. Van Slyke, Ph. D.,
Chemist.

[1]Edwin B. Hart, B. S.,
Associate Chemist.

[2]William H. Andrews, B. S.,
[3]Christian G. Jenter, Ph. C.,
Frederick D. Fuller, B. S.,
[2]Charles W. Mudge, B. S.,
Andrew J. Patten, B. S.,
[2 4]Frank A. Urner, A. B.,
Assistant Chemists.

Harry A. Harding, M. S.,
Dairy Bacteriologist.

[5]John F. Nicholson, M. S.,
[6]Martin J. Prucha, Ph. B.,
Assistant Bacteriologists.

George A. Smith,
Dairy Expert.

Frank H. Hall, B. S.,
Editor and Librarian.

[7]Victor H. Lowe, M. S.,
[8]Percival J. Parrott, M. A.,
Entomologists.

[9]Howard O. Woodworth, M. S.,
Assistant Entomologist.

Spencer A. Beach, M. S.,
Horticulturist.

Vinton A. Clark, B. S.,
Assistant Horticulturist.

Orrin M. Taylor,
Foreman in Horticulture.

[10]F. Atwood Sirrine, M. S.,
Special Agent.

Frank E. Newton,
Jennie Terwilliger,
Clerks and Stenographers.

Adin H. Horton,
Computer.

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[1]Assistant Chemist before September 1, 1903.
[2]Connected with Fertilizer Control.
[3]Absent on leave.
[4]Appointed July 20, 1903.
[5]Resigned July 21, 1903.
[6]Appointed September 14, 1903.
[7]Died August 27, 1903.
[8]Appointed September 15, 1903.
[9]Resigned September 1, 1903.
[10]In Second Judicial Department.

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Twenty-Second Annual Report

of the

Board of Control of the New York Agricultural Experiment Station.

TREASURER'S REPORT.

Geneva, N. Y., *October* 1, 1903.

To the Board of Control of the New York Agricultural Experiment Station:

As Treasurer of the Board of Control, I respectfully submit the llowing report for the fiscal year ending September 30, 1903:

Appropriations, 1902-1903.

Receipts.

GENERAL EXPENSES.

1902.				
Oct.	1.	To balance		$4,594 29
		To amount received from Comptroller	$20,000 00	
		To amount charged in 1902 report as due from Comptroller	4,000 00	
				16,000 00
				$20,594 29

Expenditures.

		By building and repairs...	$2,507 59	
		By chemical supplies.....	399 09	
		By contingent expenses...	2,108 76	
		By feeding stuffs........	1,953 12	
		By fertilizers	25 08	
		By freight and express....	557 69	
		By furniture and fixtures.	1,131 29	
		By heat, light and water...	3,206 83	
		By library	692 59	
		By live stock............	235 00	
		By postage and stationery.	863 31	
		By publications	1,545 00	
		By scientific apparatus....	27 55	
		By seeds, plants and sundry supplies	1,406 01	
		Tools, implements and machinery	968 60	
		By traveling expenses....	1,079 41	
1903.				
Oct.	1.	By balance	$1,887 37	
				$20,594 29

SALARIES.

Receipts.

1902.				
Oct.	1.	To balance		$5,408 08
		To amount received from Comptroller	$27,500 00	
		To amount charged in 1902 report as due from Comptroller	5,500 00	
				22,000 00
				$27,408 00

Expenditures.

1903.				
		By salaries	$21,410 17	
Oct.	1.	By balance	5,997 91	
				$27,408 08

LABOR.

Receipts.

1902.				
Oct.	1.	To balance		$3,436 03
		To amount received from Comptroller	$15,000 00	
		To amount charged in 1902 report as due from Comptroller	3,000 00	
				12,000 00
				$15,436 03

Expenditures.

1903.				
		By labor	$12,458 97	
Oct.	1.	By balance	2,977 06	
				$15,436 03

COMMERCIAL FERTILIZERS.

Receipts.

1902.				
Oct.	1.	To balance		$3,677 75
		To amount received from Comptroller	$12,500 00	
		Amount charged as due Comptroller in 1902 report	2,500 00	
				10,000 00
				$13,677 75

Expenditures.

		By chemical supplies	$237 93	
		By contingent expenses	1 65	
		By freight and express	55 21	
		By furniture and fixtures	18 20	
		By heat, light and water	603 99	
		By postage and stationery	208 78	
		By publications	1,070 40	
		By salaries	5,355 85	
		By seeds, plants and sundry supplies	14 90	
		By tools, implements and machinery	1 00	
		By traveling expenses	994 35	
1903.				
Oct.	1.	By balance	5,115 49	
				$13,677 75

CONCENTRATED FEEDING STUFF INSPECTION.

1902.		*Receipts.*		
Oct.	1.	To balance		$309 33
		To amount received from Comptroller	$2,900 00	
		To amount charged as due from Comptroller in 1902 report	400 00	
				2,500 00
				$2,809 33

Expenditures.

By contingent expenses	$0 95
By freight and express	75 36
By postage and stationery	13 99

		By publications	$365 00	
		By salaries	1,140 80	
		By seeds, plants and sundry supplies	39 10	
		By traveling expenses....	547 92	
1903.				
Oct.	1.	By balance	626 21	
				$2,809 33

2D JUDICIAL DEPARTMENT.

Receipts.

1902.				
Oct.	1.	To balance		$2,462 06
		To amount received from Comptroller	$6,880 01	
		To balance amount appropriated	1,129 99	
				8,000 00
				$10,462 06

Expenditures.

By chemical supplies......	$56 04	
By contingent expenses...	18 07	
By fertilizers	55 98	
By freight and express....	24 49	
By heat, light and water...	11 27	
By labor	120 20	
By postage and stationery.	4 09	
By publications	1,713 42	
By salaries	3,848 20	
By scientific apparatus....	10 00	
By seeds, plants and sundry supplies	71 82	

	By tools, implements and machinery	$35 40	
	By traveling expenses	786 77	
	By rents	124 18	
1903.			
Oct. 1.	By balance	3,582 05	
			$10,462 06

APPROPRIATION 1901-1902.

REPAIRS TO OFFICE BUILDING.

Receipts.

To amount received from Comptroller	$8,234 75

Expenditures.

By construction	$7,907 75	
By equipment	327 00	
		8,234 75

INSURANCE MONEY.

1902.		
Oct. 1.	To balance	$8,541 20

Expenditures.

	By buildings and repairs	$6,294 63	
	By live stock	385 00	
	By seeds, plants and sundry supplies	73 50	
1903.	By tools, implements and machinery	680 00	
Oct. 1.	By balance	1,108 07	
			$8,541 20

FERTILIZER LICENSE, 1902-1903.

Receipts.

To amount received for fertilizer license	$13,220 00

Expenditures.

By amount remitted to the Treasurer State of New York	$13,220 00

FEEDING STUFF LICENSE, 1902-1903.

Receipts.

To amount received for feeding stuff license	$3,675 00

Expenditures.

By amount remitted to the Treasurer State of New York	$3,675 00

All expenditures are supported by vouchers approved by the Auditing Committee of the Board of Control and have been forwarded to the Comptroller of the State of New York.

UNITED STATES APPROPRIATION, 1902-1903.

Receipts.

To receipts from the Treasurer of the United States as per appropriation for fiscal year ending June 30, 1903, as per act of Congress, approved March 2, 1887	$1,500 00

Expenditures.

By salaries	$120 00
By publications	549 90
By postage and stationery	284 35
By heat, light, water and power	125 00
By chemical supplies	41 95
By seeds, plants and sundry supplies	47 50

By fertilizers	$144 50	
By feeding stuffs....................	14 00	
By live stock........................	105 00	
By contingent expenses.............	67 80	
		$1,500 00

WILLIAM O'HANLON,
Treasurer.

DIRECTOR'S REPORT FOR 1903.*

To the Honorable Board of Control of the New York Agricultural Experiment Station:

Gentlemen.—I have the honor to submit herewith my report as Director for the year 1903. It is a pleasure to report that the year has been one of general prosperity in the affairs of the Station, although some conditions have been embarrassing, chiefly those occasioned by the disastrous fire of the previous year. Broadly speaking, experiment stations in their organization and work are, I believe, approaching each year more nearly their true function and the relation of helpfulness which they should sustain to the art of agriculture. In this respect the New York Station is, I trust, not an exception. It is certainly true that each year brings to it a closer relationship to agricultural practice and a greater number of increasingly complex problems for solution.

In what follows I have endeavored to set forth the present status of the institution, the changes and results for the year that is past and the more pressing needs for the future.

CHANGES IN THE STATION STAFF.

The frequency of changes in the Station staff noted for the year 1902 have continued, through various causes, during 1903. Other institutions seem disposed to forage on us when they are in need of men, and while from one point of view this is a matter for congratulation, it is no less embarrassing at times.

It is with unspeakable regret that I must record here the death of Victor H. Lowe, M.S., Entomologist to the Station, which

*A reprint of Bulletin No. 244.

occurred at Fort Collins, Colorado, on Aug. 27th. Mr. Lowe became connected with the Station in 1894, being first located at the branch office at Jamaica, L. I. In 1896 he was transferred to Geneva and was placed in charge of the entomological work of the institution. Judged by the character of his work and by the personal and social relations which he easily established, Mr. Lowe met with unusual success. He combined in a rare manner the ability to accomplish results which secured the approval both of his professional associates who were looking for well established scientific data and of the men of practice who were seeking for aid on the farm and in the orchard. He developed, moreover, into a most popular platform speaker in the presentation of the results of his investigations. Mr. Lowe's influence as a station official was greatly strengthened by his personality which not only inspired confidence in the integrity of all his purposes but drew to him a large circle of friends. His death creates a deep sense of personal loss in all who knew him intimately, for he was a devoted friend and a faithful and loyal co-worker.

Mr. Percival J. Parrott, M.A., was appointed to succeed Mr. Lowe as Entomologist to the Station and entered upon his duties Oct. 1st. Mr. Parrott was formerly a member of the Station staff as Assistant Entomologist. This position he resigned to become Entomologist to the Ohio Experiment Station, at which institution he was meeting with marked success when asked to return to New York.

Mr. E. B. Hart, Assistant Chemist, in view of the ability which he has shown in the field of chemical research, has been promoted to the rank of Associate Chemist.

Mr. John F. Nicholson, B.S., Assistant Bacteriologist, resigned to accept a similar position at the Oklahoma Agricultural and Mechanical College.

Mr. Martin Prucha, Ph.B., a recent graduate of Wesleyan University, where he specialized in bacteriology, was appointed to fill the vacancy occasioned by Mr. Nicholson's resignation.

Mr. Frank A. Urner, A.B., a graduate of Cornell University, where he specialized in chemical studies, was appointed to a vacancy occasioned by the resignation of Mr. J. Arthur LeClerc in 1901.

Mr. Howard O. Woodworth, M.S., resigned his position as Assistant Entomologist and accepted a position in California. No one has, as yet, been appointed to succeed him.

It is to be regretted that the assistants in the various departments of the Station are being called to other institutions at higher salaries after comparatively short periods of service with us. While this indicates that worthy and desirable men are selected for appointment to this staff, it is obvious that such frequent changes can but result in injury to our work. It is extremely desirable that such arrangements shall be made in the future with reference to the term of service of our assistants, under conditions which they shall consider desirable, that changes shall be less frequent.

THE FUNCTION OF THE STATION.

The institutional efforts now put forth in the interest of agriculture involve three general and distinct functions: (1) Research, which, broadly speaking, includes the discovery of new principles and facts and the application of these principles and facts to the processes of the farm; (2) instruction in known facts, which includes the teaching of students at a school or college and the spreading of information in a popular way among the agricultural people; (3) the protection of the people by law against fraud and against the spread of pests and other untoward conditions.

The institutions created by law which exercise these various functions are the experiment station, the college, the school, the farmers' institute, the fair, and state departments charged with duties of a purely administrative or executive character. Each institution or department is equipped with men and means adapted to its work. While the several functions enumerated have to some extent been

exercised by the same institution, experience has shown that the same group of men cannot combine, with the largest degree of success, duties so unlike in character as those here enumerated. As a rule the teacher, under the conditions prevailing in the United States, whether in the academic or in the popular field, finds little time for investigation; and neither the investigator nor the teacher should be greatly burdened with duties of an administrative character, because such consume time and are antagonistic to a studious or reflective state of mind. The present tendency is certainly towards the differentiation of institutions along the line of functions.

The peculiar function of the experiment station is investigation and experimentation. The New York Agricultural Experiment Station is organized and managed in a way that is consistent with this function and its work neither duplicates the work of any other state institution nor is it an infringement thereof. It teaches no students, it engages in inspection work only in those lines which seem to require close association with scientific laboratories and with professional knowledge, and it engages in popular instruction at institutes only to the extent necessary to spread a knowledge of its work and results and to place its staff in touch with the problems that confront farmers. There is in New York an inter-relation between the station, the college, the Department of Agriculture and the farmers' institutes which is helpful, but which constitutes neither duplication nor interference. The work of the Station is more fertile of useful results because the members of its staff are able to devote themselves with singleness of purpose to the discovery and application of truths that are important to the farmers' art.

THE GROWTH OF THE STATION AND ITS SUPPORT.

The New York Agricultural Experiment Station was organized over 21 years ago. During this period its activities have become greatly enlarged, with a corresponding increase in income and equip-

ment. It is hardly to be expected that this growth has ceased. The scope and relations of experiment station work are steadily broadening. Agricultural practice is coming to rely more and more, as time passes, on the expert information and processes that so largely originate in scientific investigations and experiments, so that the experiment station is now an increasingly essential factor in agricultural affairs. While the time has come when such a view of the experiment station work is so evidently correct as scarcely to need a supporting argument, it is wise to summarize occasionally the facts which justify a continuance, or even an increase, of the public support given to the Station in New York; and thus to present a concise expression of facts which are seen in their full significance only by those who are entirely familiar with the growth of the Station and its activities during its history.

Establishment of the Station.—The New York Agricultural Experiment Station was established in 1880 by an act of the legislature passed June 26th, constituting Chap. 592, laws of 1880.

Geneva was selected as its location and the first director took possession of the Station property on March 1st, 1882. The equipment then consisted of 125 acres of land with the usual farm buildings, fruit orchards of reasonable size, and a scientific and clerical staff of five persons. Scientific laboratories and apparatus were entirely wanting.

The sum of $20,000 was made available annually for the support of the Station.

Increase in buildings and other equipment.—The buildings acquired with the Station property were a mansion-house and the usual outbuildings.

The following are the buildings now situated on the Station grounds: A thoroughly equipped Chemical Building containing four laboratories, accommodating a large force of chemists necessary to the research and inspection work carried on by the Station; a Bio-

logical and Dairy Building in which are located the departments of bacteriology, botany, entomology, horticulture and dairying, together with five well-equipped laboratories; an Administration Building which is devoted wholly to administrative offices and the library; forcing houses with 6,500 feet of glass; poultry houses built for experimental work; a fine cattle barn; a horse stable in process of construction; six dwelling houses and various small buildings.

This increase in buildings has nearly all been effected since 1890, more than half of it having been secured since 1896. It has brought with it a corresponding increased expense for care, heating and repairs.

The farm has been improved from a somewhat run down condition to a satisfactory state of fertility. On it has been developed one of the finest collections of living fruits, large and small, to be found in the world, and nearly all of the land is used for strictly experimental purposes. The cost of maintaining such a farm can scarcely be appreciated by those who have had no experience in such matters.

Increase of staff and employees.—Since 1882 the scientific staff has increased from four members to twenty-one. Eight members have been added since 1896. The clerical force has increased from one person to four.

The addition to the buildings and laboratories, as well as the large increase of experimental work, both in the laboratories and in the field, have rendered necessary a corresponding increase in the number of employees such as laboratory helpers, janitors, forcing house assistants, herdsmen, teamsters and common laborers.

Increase in work.—Since 1875 control of a scientific basis has invaded every department of agricultural activity. The agricultural practitioner now relies upon the experiment station for advice along certain lines where expert processes are important. This is especially true of this State, 56 per ct. of whose products are those which are

especially susceptible to scientific aid. This is shown, for instance, by the present relations of the Station to the control of commercial dairying, the use of spraying mixtures and other means for controlling injurious insects and fungi, the study of fertility and feeding problems, the investigation of horticultural problems and aid given in the purchase of fertilizers and feeding stuffs.

It is further shown by the fact that experiments have been carried on or are planned in 29 localities outside the Station laboratories and farm during the past two years. These experiments have included the use of cover crops, systems of managing apple orchards, the relative value of certain stocks for grape production, the commercial value of dwarf apple orchards, studies of the fertility of grapes, profits from shading strawberries, value of foreign varieties of chestnuts, financial results from spraying potatoes, prevention of certain cabbage diseases, prevention of red spot or rust in cheese, control of the San José scale and studies of certain troubles in canning peas.

Moreover, coöperative work in several lines has been carried on with the United States Department of Agriculture, notably in ascertaining the possibilities of producing high grade sugar beet seed in this State, in testing new forage crops, in studying the value of a large number of varieties of apples for cold storage purposes and in ascertaining the financial outcome of cold storage of cheese combined with the paraffining process.

The financial value of experiment station work.—It is not easy to express this value in exact terms. That it is far greater than the cost of the Station can easily be made evident, however.

There are 226,000 farms in New York. If the Station makes possible one dollar more profit yearly on each farm, the institution is a profitable investment. That intelligent farmers are helped many times this amount cannot be successfully questioned. We should consider, for instance, what our condition would be if there was no systematic study of the great problems of fertility and of plant and animal life, if we had no defence against the diseases and insects that

infest farm crops and fruits, if no remedies were found for the troubles that afflict the dairyman, if science had lent no aid in preventing frauds that directly affect the farmer's pocketbook, and if we were still in the days of tradition and superstition concerning Nature's ways. If specific instances of station work need to be cited to make its value clear, mention may be made of the spraying of potatoes with a possible saving of millions of dollars yearly, of the study and control of the San José scale that threatened our fruit interests with their annual income of not less than $15,000,000, of the saving of the pickle industry on Long Island against the ravages of a fungus pest, of the means provided for controlling troubles affecting value of cheese and of information gathered by Station activity showing that this State is adapted to the production of sugar beets of the highest grade.

THE FINANCIAL SUPPORT AND NEEDS OF THE STATION.

Past expenditures.—It should be freely acknowledged that the State has been reasonably generous towards its experiment station. The annual income for the maintenance of all its work was at first $20,000 and Oct. 1st, 1904, it had become $69,500 in accordance with the following items:

For maintenance fund	$50,000
For outside horticultural investigations	8,000
For enforcing provisions of the fertilizer law	10,000
From United States Government	1,500
Total	$69,500

This continued to be the annual maintenance income of the Station until the fiscal year 1899-1900.

The legislature of 1899 amended the fertilizer law so as to require the payment annually of a license fee on the various brands of fertilizers, the same to be used in administering the law, and also passed

a law requiring the inspection of cattle foods by the Station, the expense of this to be met also from license fees.

From 1899 to Oct. 1st, 1903, the receipts of the Station for the maintenance of its various lines of work where as follows:

Maintenance fund	$50,000	
For outside horticultural investigations	8,000	
Total raised by taxation		$58,000
Enforcement of Fertilizer Law, from license fees	$10,000	
Enforcement of Feeding Stuff Law, from license fees	2,500	
Total from license fees		12,500
From United States Government		1,500
Total annual income of Station for period stated		$72,000

The amount hitherto given for outside horticultural investigations was not appropriated for the fiscal year 1903-4, so that, for the coming year, the revenue of the Station will be $8,000 less than for many years previous, the total income from the State being $62,500. Of this, only $50,000 is raised by taxation, a sum $18,000 less than was appropriated annually for five years previous to 1899 when the expense of inspection work was met directly by the State, instead of indirectly, by license fees, as is the case at present. This is the financial situation notwithstanding the growth of the institution.

For the fiscal year 1894-5 the cost of maintaining the work of the Experiment Station, exclusive of inspection, was approximately $6,200 for each member of the scientific staff. For the fiscal year 1902-3 the cost of maintaining the institution, exclusive of inspection, averaged only $3,600 for each member of the scientific staff. It is not intended by this comparison to imply that in the earlier days of the Station there was any extravagance or unwisdom in the use of funds but simply to show that through careful management the Station has been able to increase its work and activities without causing added expense to the state.

Increase in buildings and other equipment.—The legislature of 1903 made appropriations for additional buildings and equipment as follows:

For horse stable and carriage house..................	$5,000
For fire protection system..............................	5,000

The horse stable and carriage house are well advanced in construction. The fire protection system is nearly installed. It will consist of a steel tower 100 ft. high surmounted by a tank holding 15,000 gallons of water. This tank is connected by a six inch pipe with hydrants so distributed as to be available to all the Station buildings of any considerable size.

A Holloway chemical engine, with two 30-gallon cylinders, has been purchased, also three hose carts with one thousand feet of 2½ inch hose. The Station is now for the first time well equipped to combat fire.

Buildings and equipment needed.—The disastrous fire of May 7th, 1902, left the Station without any building for the storage of farm machinery and other materials which should not be located either in a cattle barn or horse stable. Such a building is imperatively needed and if so built as to accommodate grain storage in vermin proof bins should cost not less than $4,500 at the present very high prices for labor and building materials.

The appropriations asked for 1904-5.—The following are the appropriations needed for the fiscal year 1904-5:

For salaries of scientific and clerical staff......	$27,500	
For wages of the labor class, including engineer, janitors, laboratory helpers, employees in forcing house and orchards, herdsmen, teamsters and common labor........................	13,000	
For general expense, including heat, light, water, laboratory supplies, outside experiments, traveling expenses, equipment of scientific apparatus, farm machinery, and general expenditures of all sorts...........................	20,000	
		$60,500

Total brought forward		$60.500
For fertilizer inspection (from license fees)	$10,000	
For feeding stuff inspection (from license fees)	3,500	
For inspection		13,500
Total		$74,000
For building for storage farm machinery and grain		$4,500

The above estimates are carefully made upon the basis of present needs, without allowing for much growth. The sum asked for outside of inspection work is $2,500 more than the Station has been receiving for the last four years but is $7,500 less than the sum appropriated for several years previous to 1899 from money raised by taxation. The sum named for feeding stuff inspection is increased by $1,000. The receipts from license fees justify this and the additional sum can be well used.

The building for farm machinery and grain is certainly a real need. The farm machinery is now scattered in out of the way places, partly outside of the Station grounds, and during the working season it cannot be housed if kept where it is convenient for use.

THE MAILING LIST.

The mailing list continues to increase steadily. The increase in the popular bulletin list during 1903 is 1,707. Of these names, 1,103 are residents of New York.

BULLETIN LISTS, JAN. 1ST, 1904.

POPULAR BULLETINS.

Residents of New York	36,384
Residents of other States	1,800
Newspapers	770
Experiment Stations and their staffs	917
Miscellaneous	131
Total	40,002

COMPLETE BULLETINS.

Experiment Stations and their staffs	917
Libraries, scientists, etc.	270
Foreign list	220
Individuals	2,265
Miscellaneous	131
Total	3,803

INSPECTION WORK.

This includes the same lines of inspection that are enumerated in previous reports:

An outline of what has been accomplished in 1903 is as follows:

Inspection of fertilizers.—As is to some extent already known, the bulletin giving the results of the analyses of fertilizers for 1903, which usually appears not later than November, has been withheld from publication, temporarily at least. The necessity of this action, due to an insufficiency of statutory provisions, is certainly to be regretted. As a result of contentions arising from complaints made by me to the Attorney-General in accordance with Section 8 of Chapter 955 of the Laws of 1896, the question of authority for the publication of the fertilizer bulletin was raised for the first time. After considering this point, the Attorney-General of the State rendered an opinion, the summary of which is as follows: "I am of the opinion, therefore, that there is no statutory authority, either mandatory or otherwise, for the publication of the results of the examinations in question, and, therefore, if the Board of Control, or the Director appointed by it, makes such publication it is subject to the same rights and liabilities as an individual would be who made such publication." Litigation was threatened if the bulletin was published, and it is clear that neither your Board nor myself should be asked to assume personally the possible burden and vicissitudes of such litigation in behalf of the State, consequently the publication of the bulletin in question was withheld. It is evident that the Fertilizer Law

should be amended to give the necessary authority for the publication of the results of the examination of samples of fertilizers.

For 1903, 83 manufacturers licensed 644 brands of fertilizers. The Station's collecting agents visited 203 towns between March 24 and August 28, obtaining 948 samples of fertilizers, representing 540 brands.

The following tabulated statement shows the average composition of the complete fertilizers collected during the year, together with a comparison of the guaranteed composition and that found by analysis:

AVERAGE COMPOSITION OF COMPLETE FERTILIZERS COLLECTED.

	Per ct. guaranteed.			Per ct. found.			Average per ct. found above guarantee.
	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	
Nitrogen	0.41	8.23	2.04	0.14	8.32	2.11	0.07
Available phosphoric acid	1.50	12.00	7.67	0.06	15.50	8.50	0.83
Insoluble phosphoric acid	——	——	——	0.01	5.84	2.05	——
Potash	0.50	15.00	4.55	0.03	13.33	4.78	0.23
Water-soluble nitrogen	——	——	——	0.00	8.91	1.02	——
Water-soluble phosphoric acid	——	——	——	0.00	11.08	5.40	——

COMMERCIAL VALUATION AND SELLING PRICE OF COMPLETE FERTILIZERS.

Commercial valuation of complete fertilizers.	Selling price of one ton of complete fertilizer.			Average increase cost of mixed materials over unmixed materials for one ton.
Average.	Lowest.	Highest.	Average.	
$19.64	$16.00	$60.00	$26.60	$6.96

In the table below we present figures showing the average cost to the purchaser of one pound of plant-food in different forms in mixed fertilizers.

AVERAGE COST TO CONSUMERS OF ONE POUND OF PLANT-FOOD IN MIXED FERTILIZERS.

Nitrogen	23.0	cents.
Phosphoric acid (available)	5.75	"
Potash	6.10	"

Inspection of concentrated feeding stuffs.—A summary of the work accomplished in this line is presented below, as shown by Bulletin 240.

(1) One hundred manufacturers have licensed one hundred and fifty-one brands of feeding stuffs for the year 1903.

The list of licensed brands may be classified as follows:

Proprietary or mixed feed	78	brands
Meat and bone meal	15	"
Distillers' grains	14	"
Hominy feed or chop	13	"
Linseed meal	9	"
Cottonseed meal	5	"
Gluten feed	6	"
Malt sprouts	4	"
Sugar beet refuse	2	"
Brewers' grains	1	brand
Corn bran	1	"
Corn oil cake	1	"
Gluten meal	1	"
Molasses grains	1	"
Total	151	brands.

(2) Five hundred eighteen samples of feeding stuffs, officially collected from October, 1902, to February, 1903, have been analyzed.

These samples may be classified as follows:

Name of feed.	No. samples.	No. brands.
Cottonseed-meal	15	8
Distillers' grains	18	8
Brewers' grains	2	2
Linseed cake, ground	4	2
Linseed oil meal	23	10
Gluten meal	2	2
Gluten feed	22	7
Hominy feed	28	11

Name of feed.	No. samples.	No. brands.
Malt sprouts	7	5
Germ oil meal	2	1
Oats, ground	7	7
Corn meal	12	12
Bran and corn meal	14	14
Mixed feeds (bran and middlings)	56	33
Wheat offals (barn and middlings, unmixed)	76	69
Proprietary and mixed feeds (mostly corn and oat products)	177	123
Poultry foods	39	25
Miscellaneous feeds (oat hulls, screenings, etc.)	14	14
Total	518	353

(3) No adulteration was observed among the cottonseed and linseed meals, gluten products and brewery and distillery residues, as shown by the official samples. Corn cobs were shown to be present in three brands of licensed feeds, in two samples of unlicensed bran and in one sample sold as pure corn meal. Several proprietary feeds were found, as usual, to be made up in part of oat hulls.

(4) Many samples of wheat offals, bran, middlings and the same mixed, were found to be unadulterated and of good quality. The same can be said of numerous samples of corn and oats ground together.

(5) The markets are offering many inferior feeding stuffs. At the same time, the great bulk of commercial cattle foods available to buyers are unadulterated and of good quality.

DEPARTMENT OF ANIMAL HUSBANDRY.

The importance of mineral matter and the value of grit.—In poultry feeding the supply of mineral matter is a most important consideration, and a number of feeding experiments have been undertaken to ascertain what deficiencies exist in ordinary foods.

In feeding chicks the beneficial results attending the use of certain animal foods were found sometimes to be due chiefly to the bone

or mineral matter which they contained. Bone ash was found to supply a deficiency existing in most rations which consisted wholly of grain and other vegetable foods.

In order to get further intimation as to the extent that the inorganic material was of nutritive value and how much of the benefit from its use might be due to mechanical assistance, certain other feeding experiments have been made.

In these tests nineteen lots of chicks were fed for either ten or twelve weeks, beginning with chicks from one to three weeks old.

The mixing of sand in the food, both in a ration containing animal food and one without, results in better health for the chicks and more efficient use of the food. The advantage of the sand was most apparent during the first four weeks.

The addition of raw ground Florida rock phosphate and sand to rations both with and without animal food resulted in better growth and more efficient use of food than when sand alone was added.

The addition of the ground rock to rations without animal food resulted in more rapid growth and more efficient use of food than the addition of sand alone.

Ground rock phosphate proved a better addition to rations both with and without animal food, than ground oyster shell. Better growth resulted and, on the whole, from less food.

Food mixed with finely ground oyster shell was less healthful and less efficient than when mixed with fine sand.

Mixing bone ash and ground oyster shell in the food resulted in more rapid growth than the mixing of sand alone, but injury attributed to the ground oyster shell made the feeding less profitable.

DEPARTMENT OF BACTERIOLOGY.

Black rot of cabbage and cauliflower.—This trouble has been studied in coöperation with the Botanical Department. The treatment by removing all diseased leaves which has been recommended

by other investigators has been found worse than useless under New York conditions. A fundamental study of the germ causing the disease is now in progress.

Cheese curing.—Work on this problem is going forward in connection with the Chemical and Dairy Departments. The publications of the year have dealt with the influence of the acid-forming bacteria upon the manaufacture and early stages of curing of the cheese.

It is found that under normal conditions both the activity of the rennet in curdling the milk and the presence of the compounds which give the characteristic texture to the cheese curd are due to the action of the acid-forming bacteria. The rennet plays a part in the first stages of cheese ripening but it can only do this in the presence of an acid reaction. This acid reaction is normally brought about by the activity of the acid-forming bacteria.

These results may be summed up in the statement that the presence and activity of the acid-forming bacteria is the first requisite to the manufacture of normal cheddar cheese.

The influence of various factors upon the later stages of curing is now being studied.

Fermentation of canned peas.—Before the opening of the canning season a circular explaining the true cause of this trouble and giving the lower limit of the heating required to prevent this fermentation was sent to the press and to all canners in the State.

Observations were continued throughout the season in a large cannery operated in accord with these suggestions. This establishment canned a ton of peas in a special experiment to determine the lower limits of temperature and time of heating to insure the destruction of the bacteria under factory conditions, as well as to determine the greatest amount of heating which could be given without injury to the quality of the peas. By this means it was found that there is a considerable range of temperature within which the peas are rendered sterile without injury to their quality.

DEPARTMENT OF BOTANY.

Potato spraying experiments.—The ten-year potato spraying experiment begun in 1902 has been continued during 1903, both at Geneva and Riverhead. Again, spraying has resulted in a large increase in yield. At Geneva the increase in yield due to three sprayings was 88 bushels per acre and that due to five sprayings, 118 bushels. At Riverhead three sprayings increased the yield 39½ bushels per acre and five sprayings increased it 56 bushels per acre.

In order to determine the actual profit in spraying potatoes under ordinary farm conditions, six business experiments were conducted in coöperation with farmers in different parts of the State. In each experiment the increase in yield was determined and an account kept of all expense. Since late blight was unusually destructive the past season, spraying proved highly profitable. On a total area of 61 1-6 acres sprayed in the six experiments there was a total increase in yield of 3746 bushels which is at the rate of 61.24+ bushels per acre. The value of 3746 bushels of potatoes was, at least, $1,873. Subtracting from this sum the total expense of spraying, $296.49, there is a remainder of $1,576.51, which is the total net profit. This is at the rate of $25.77+ per acre.

It is estimated that the loss from potato blight in New York in 1903 was fifty bushels per acre on the average. Since the acreage of potatoes in the State is about 396,000 acres and the average price of potatoes last fall fifty cents per bushel, the total loss sustained by New York farmers was nearly $10,000,000. A large part of this loss might have been prevented by spraying.

The results obtained by the Station, during the past two years especially, indicate plainly that the spraying of potatoes is a subject which should receive careful consideration by every potato grower in the State.

Unusual apple decays.—During March there was reported to the Station by apple dealers the occurrence of an uncommon decay of

apples in storage. The trouble was investigated and determined to be caused by a fungus, a species of *Hypochnus,* which had never before been known to cause a decay of fruit.

It was found that the fungus always entered a fruit through breaks in the skin made by scab, and investigations showed that it was impossible for it to grow through the unbroken skin. From the fact that only fruit affected with the scab was attacked by the rot the importance of preventing the scab by spraying is again emphasized.

In February, 1903, it was observed that a core rot of Baldwin apples was quite prevalent. Outwardly a fruit would appear perfectly sound, while an area about the core was decayed. An investigation did not reveal the trouble to be traceable to fungi or bacteria. A cause could not be found in the use or absence of fertilizers, soil conditions or imperfect ripening of the fruit. That it may have been due to overbearing or the excessively wet season, or to a combination of both of these factors is a possibility.

Commercial cold storage (30° F.) entirely checked the development of the decay.

Combating the black rot of cabbage.—This work has been done in coöperation with the Department of Bacteriology. During four consecutive seasons, 1899–1902, field experiments were made on the removal of diseased leaves as a means of preventing cabbage black rot, a method which has been recommended by certain other investigators. Each season the area of the experiment field was one acre, one-half receiving treatment and the other half being left untreated for a check. On the treated half acre all diseased leaves were removed from the plants and carried out of the field once a week.

In the first three seasons there was so little black rot, even on the check, that no conclusions could be drawn from the experiment; but in 1902 there was a moderate attack of the disease and the results show conclusively that this method of treatment is not only a failure

but worse. The treatment actually reduced the yield by 5,285 pounds on one-half acre, which is at the rate of 5¼ tons per acre.

The treatment fails for four reasons:

(1) The removal of so many leaves reduces the vitality of the plants; (2) infection occurs through the roots as well as by way of the leaves; (3) infection may occur at the base of the leaf close to the stem and get into the stem unobserved; (4) the germs of the disease are so widely distributed that it is useless to try to stamp out the disease by the removal of diseased material.

No successful method of combating the disease is known. Further investigations on the subject are in progress.

DEPARTMENT OF CHEMISTRY.

In addition to the work done in the different lines of inspection, the Chemical Department has been carrying on lines of work as follows:

The relation of acids in the process of cheese-manufacture to the ripening of cheese.—The study of the relation of paracasein monolactate, which was first discovered and identified in this laboratory, to the ripening of cheese, has been continued; and it has been shown that this compound is of great importance in cheese-making and cheese-ripening, forming the essential compound with which the cheese-ripening process begins. The influence of such factors as time, temperature, moisture, salt and rennet, upon the disappearance of paracasein monolactate in cheese has been carefully studied from a chemical standpoint.

The sources of carbon dioxide in cheese-ripening.—The results of this chemical work suggest that in normal cheese certain changes occur that can be attributed only to living organisms, which remain yet to be discovered by biologists.

Rennet-enzyme as a factor in cheese-ripening.—This work, largely chemical, has been carried on in connection with the Bacteriological

Department. It has been proved that rennet is a peptic enzyme and as such is able to digest the paracasein monolactate of cheese to some extent, but it does not appear to form the compounds that produce the flavor of cheese.

Conditions affecting chemical changes in cheese-ripening.—In this work a strictly chemical study has been made of the more prominent conditions that influence the changes taking place in cheese during the ripening process. The factors studied are such as time, temperature, moisture content of cheese, size of cheese, varying quantities of salt, different amounts of rennet, and acid. The facts discovered have an important practical bearing upon the conditions of the manufacture of cheese and of cheese-ripening.

Experiments in curing cheese at different temperatures, with and without a covering of paraffin.—This was a most valuable piece of work, carried on in coöperation with the U. S. Department of Agriculture. The results are very striking and may be briefly summarized as follows:

(1) The loss of cheese is less at low temperatures, and therefore there is more cheese to sell.

(2) The commercial quality of cheese cured at low temperatures is better and this results in giving the cheese a higher market value.

(3) Cheese can be held a long time at low temperatures without impairment of quality.

(4) By utilizing the combination of paraffining cheese and curing it at low temperatures, the greatest economy can be effected.

Studies of phosphorus.—The status of phosphorus in certain vegetable and animal materials has been studied. A method has been developed by which the amounts of organic and inorganic phosphorus can be differentiated. This work has been preliminary to a proposed study of the metabolism of phosphorus in the animal body.

DEPARTMENT OF ENTOMOLOGY.

Further experiments with sulphur sprays for San José scale.— The investigations of this Department for the year were largely directed towards obtaining an efficient sulphur spray, which could be more conveniently prepared than the lime-sulphur-salt wash. In some preliminary tests conducted to this end in 1902, a wash consisting of 33 pounds lime, 16½ pounds sulphur, 4-6 pounds caustic soda or potash, and 50 gallons of water, appeared to have this qualification and proved to be the most satisfactory of the various formulæ tested.

To ascertain its value under average orchard conditions for the control of scale and the prevention of plant diseases, extensive experiments, with the coöperation of the Horticultural Department, were conducted with the wash at Queens, L. I., Yorktown and Carlton Station. The trees treated numbered 1214, of which 375 are peaches, 287 pears, 5 cherries, 225 plums, 26 quinces and 296 large apples.

In September an examination was made to determine the effects of the treatment upon the scale and fruit diseases. The results upon the scale were variable. In some cases the treatment affected an almost entire destruction of the insects, while in others the numbers of the scale seemed to have been but little affected. This variability seems to have been due to the lack of sufficient heat from the lime and soda to make the necessary sulphur compounds. Owing to the slight attacks of diseases in these orchards, the fungicidal value of the wash was not determined. Apple scab and sooty blotch were almost entirely absent. The fruit of the checks and treated trees seemed to be equally free from these troubles. Peach leaf curl, while more prevalent, was not sufficiently abundant to indicate the merits of the wash for its prevention.

In view of the varying results obtained, investigations are being made to determine methods by which the wash may be made uniform in all preparations. For the present this wash is advised only for experimental purposes. As the lime-sulphur-salt wash has proven

more satisfactory, it is recommended for the treatment of the scale. Directions for its preparation and application are given in Bulletin 228.

The peach snout beetle (*Anametis granulatus* Say).—Observations upon this insect were begun last year and are being continued. It has apparently not been recognized as a species of economic importance till this year when its destructive attacks upon young peach trees entitle it to a place upon the list of injurious insects. The life history of this species is not fully known. The beetles make their appearance in early May. They feed at night upon the foliage, and during the day remain partially concealed in the ground. Some new facts upon the egg-laying habits were obtained. The eggs were usually deposited in folds of the leaves or between two leaves, drawn and glued together.

The habits of the beetles indicate two methods of treatment; first, catching the beetles at night by means of a curculio catcher; and second, spraying trees with arsenate of lead once before buds burst and again after blossoms have fallen.

HORTICULTURAL DEPARTMENT.

Thinning apples.—Observations have been made on the effect of thinning apples upon the color, size and market value of the fruit; also upon the amount and regularity of fruit production. The thinning was done during June and July. The experiments were continued with the same trees for four consecutive years. These trees were mature, in good condition and well cared for. Under certain conditions thinning improved the size, color and market value of the fruit, but with the trees under experiment it had no appreciable effect upon either the amount or regularity of fruit production.

Spray apparatus and spray mixtures.—No small part of the Station's correspondence relates to plant diseases and injurious insects and the treatment of the same. To assist in answering questions which are appearing in such correspondence and to put in concise,

readily available form the notes and observations acquired in Station experience, Bulletin 170 was prepared in 1899, by the Horticulturist, Botanist and the Entomologist. It gives popular information concerning diseases and insects injurious to orchard fruits. A revised edition of this is now available, embodying recent notes. This is now supplemented by a bulletin from the Horticultural Department on spraying apparatus and spray mixtures, which gives an up-to-date account of the preparation and application of liquid fungicides and insecticides, including illustrated descriptions of spraying apparatus. It is, in fact, designed for a handbook on this subject embodying classified information drawn from experimental tests and from years of Station experience in orchard and field work, as well as from correspondence and personal interviews with orchardists and others who use spray mixtures extensively and successfully. This bulletin is well worthy of being kept for reference.

BULLETINS PUBLISHED IN 1903.

No. 230. February. Some facts about commercial fertilizers in New York State. L. L. VAN SLYKE. Pages 18.

No. 231. February. The relation of carbon dioxide to proteolysis in the ripening of cheddar cheese. L. L. VAN SLYKE and E. B. HART. Pages 23.

No. 232. April. Combating the black rot of cabbage by the removal of affected leaves. F. C. STEWART and H. A. HARDING. Pages 23.

No. 233. June. Rennet enzyme as a factor in cheese-ripening. L. L. VAN SLYKE, H. A. HARDING and E. B. HART. Pages 30.

No. 234. July. Experiments in curing cheese at different temperatures. (In coöperation with the U. S. Department of Agriculture.) L. L. VAN SLYKE, G. A. SMITH and E. B. HART. Pages 25.

No. 235. July. Two decays of stored apples. H. J. EUSTACE. Pages 9, plates 4.

No. 236. July. Conditions affecting chemical changes in cheese-ripening. L. L. VAN SLYKE and E. B. HART. Pages 31.

No. 237. July. The role of the lactic acid bacteria in the manufacture and in the early stages of ripening of cheddar cheese. H. A. HARDING. Pages 16.

No. 238. August. The status of phosphorus in certain food materials and animal by-products, with special reference to inorganic forms. E. B. HART and W. H. ANDREWS. Pages 16.

No. 239. September. Thinning apples. S. A. BEACH. Pages 30, plates 2.

No. 240. September. Inspection of feeding stuffs. W. H. JORDAN and F. D. FULLER. Pages 38.

No. 241. December. Potato spraying experiments in 1903. F. C. STEWART, H. J. EUSTACE and F. A. SIRRINE. Pages 42, plates 12.

No. 242. December. The importance of mineral constituents and the value of grit for feeding chicks. W. P. WHEELER. Pages 24.

No. 243. December. Spray mixtures and spraying machinery. S. A. BEACH, V. A. CLARK and O. M. TAYLOR. Pages 60, plates 15.

No. 244. December. Director's report for 1903. W. H. JORDAN. Pages 22.

W. H. JORDAN,
Director.

New York Agricultural Experiment Station,
Geneva, N. Y., Dec. 31, 1903.

REPORT

OF THE

Department of Animal Husbandry.

W. H. Jordan, *Director.*

W. P. Wheeler, *First Assistant.*

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I. The importance of mineral matter and the value of grit for chicks.

REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY.

THE IMPORTANCE OF MINERAL MATTER AND THE VALUE OF GRIT FOR CHICKS.*

W. P. WHEELER.

SUMMARY.

Because of the importance of the mineral nutrients in poultry feeding, experiments have been made to ascertain what deficiencies may exist in ordinary foods.

For chicks the benefit of certain animal foods was found to be sometimes chiefly due to the mineral matter they contain. Bone ash was found to supply a deficiency existing in most grain rations. It is desirable to know to what extent certain inorganic material of this kind is of direct nutritive value and how much it is of purely mechanical assistance.

As a help toward information in this line feeding experiments were made, some of which, with chicks, gave the results here reported.

The mixing of sand in the food—both in a ration containing animal food and one without—resulted in better health for the chicks and more efficient use of the food.

The addition of raw, ground Florida rock phosphate and sand to rations both with and without animal food resulted in better growth and more efficient use of food than when sand alone was added.

*A reprint of Bulletin No. 242.

The addition of the ground rock to rations without animal food resulted in more rapid growth and more efficient use of food than the addition of sand alone.

The addition of ground rock phosphate to rations both with and without animal food was followed by better growth, and on the whole from less food, than the addition of finely ground oyster shell.

Food mixed with finely ground oyster shell was less healthful and less efficient than the same food mixed with fine sand.

Mixing bone ash and ground oyster shell in the food resulted in more rapid growth than the mixing of sand alone. But injury attributed to ground oyster shell made the feeding less profitable.

INTRODUCTION.

In the feeding of animals the mineral nutriments have not always been given consideration. Although their importance has been recognized, but little practical disadvantage came from the usual neglect to consider them. For most purposes so far as we know, the common foods carry enough of the ash constituents. Sometimes for rapidly growing young they do not.

But in feeding poultry the supply of mineral matter must usually be considered. It constitutes over 35 per ct. of the total dry matter of the egg, and the growth of the young is retarded when there is an insufficient supply.

While less than 10 per ct. of the body of the fowl would be left in the ash, this body, including the bony framework, is very rapidly formed. The young of most birds grow very fast. Chickens often show a gain in weight of over 1500 per ct. during the first ten weeks, and at times ducklings increase in weight from 50 to 100 per ct. a week.

With such rapid transformation it is very important that no essential material should be lacking in the food. If it must be obtained by too slow accumulations the normal growth is retarded. Growth

once checked is seldom so profitably resumed nor in its ultimate attainment so satisfactory. This is known in milk flow and in egg laying. It is easier to sustain the flood of production than to restore it after any subsidence.

Because of the importance of the mineral nutrients in poultry feeding, experiments in which they are considered were some time ago undertaken at this station. The ordinary grain foods are notably low in lime content; but it was found that laying hens could readily obtain this necessary material, when demanded, from inorganic sources such as oyster shells, etc. While the grain foods hold considerable phospherous in organic combination, it appears that more is needed by the growing chicks, for the benefit accompanying the use of animal foods was found to be often very largely due to the mineral matter which they contained.

In a number of feeding trials with chicks reported in former bulletins it was found that rations containing animal food gave much better results than similar rations without animal food, and that when the deficiency of mineral matter was supplied by the addition of bone ash, certain rations, otherwise entirely of vegetable origin, were as efficient as those containing much animal food.

Although the chicks for these experiments were kept in pens which had sand-covered floors, and were free to pick up all sand desired, it was afterward thought that much of the benefit from the addition of bone ash to the food might possibly be due to its mechanical use as grit, for it was not all finely powdered. To a limited extent this mechanical use probably did help; for when sand was added to the food of chicks, even those kept on sanded floors, better results followed.

To get testimony on this point and further intimation as to the availability of inorganic lime and phosphorus a number of feeding trials were made. Some of these were carried on about the time of feeding experiments reported earlier (Bulletin 171), but so many

chicks were taken at one time by crows and at another by rats that confidence was not felt in the significance of the results until it was strengthened by supplementary feeding trials.

When the death of any weaker chicks is apparently effected or hastened by unusual ration the final net production of the lot is the better indication of the efficiency and practicability of the ration, but when numbers are lost through accident obviously unrelated to the food, the average individual results from the different periods are the better guide. The general appearance of health and vigorous condition or its opposite counts for much with the feeder though not always indicated plainly by the mathematical data collected. In some feeding trials there was more contrast apparent than the rates of gain in weight alone would suggest.

It sometimes happens with small lots of chicks that one is favored as the age increases by the preponderance in number of males over females not distinguishable at the start. This seldom occurs with larger lots. Fortunately in these experiments contrasted lots seldom differed much on this score, possibly because of the very careful division of the lots of young chicks.

The feeding trials usually extended over ten or twelve weeks beginning with chicks from one to three weeks old.

The several experiments reported in this bulletin were made at different times when opportunity offered, during several years. Various rations were used for the different groups; but all contrasted lots were fed alike except for the added sand or mineral matter.

The data from the several feeding trials are given in the tables which follow, averaged for periods of two weeks. Nearly all the chicks used were Leghorns and attained only moderate weights during the time covered by each feeding trial.

CONDITIONS GOVERNING EXPERIMENT.

VALUATIONS OF FOODS.

The food cost for the growth made is of minor significance so far as it relates to these experiments, but is included in the data. The prices of foods taken with the first feeding trials were retained for all, although for some foods they are lower than those now generally quoted. The weight of any chicks that died was accounted loss in weight when estimating the cost of growth.

The valuations taken were as follows: For wheat bran, corn meal and malt sprouts $17 per ton, for wheat middlings, ground oats and pea meal $18 per ton, for germ gluten meal and low grade flour $22.50 per ton, for Chicago gluten meal $25, cream gluten meal $29, linseed meal $27, bone ash and animal meal $40, meat meal $35, and for blood meal $50 per ton. Wheat was rated at 78 cents per bushel and corn at 45 cents, green forage at $2 per ton, Florida rock at $10 per ton and oyster shell at 75 cents per hundred pounds.

RATIONS FOR GROUPS A AND B.

The rations for lots of chicks I and II consisted of wheat, cracked corn, corn meal, blood meal, green alfalfa and a mixture (1) composed of 4 parts of cream gluten meal, 2 parts each of low grade wheat flour and pea meal, and 1 part each of corn meal, wheat middlings and blood meal. To the ration for lot I were added 2 ounces of finely ground Florida rock phosphate and 1 ounce of fine white glass sand to every 24 ounces of the dry food, and fed mixed with the ground grain. To the ration for lot II the same amount of sand was added, except that during the first two weeks twice as much sand was used as for lot I.

The ration for lots III and IV consisted of the same foods used for lots I and II, in slightly different proportion. Lot III was fed ground Florida rock in the same amount given to lot I and lot IV was fed ground oyster shell equal to one-fourth the weight of the rock fed to lot III.

TABLE II.—CHICKS OF LOT I.—GROUP A.

RATION CONTAINING ANIMAL FOOD AND WITH LOW PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period.																Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food each pound gain in wt.
				Mixture 1.	Corn meal.	Blood meal.	Wheat	Cracked corn.	Alfalfa	Florida rock.	Sand	Protein in food.	Ash in food besides rock.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.					
	Weeks	Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Cts.		Ozs.	Ozs.	Cts.	Lbs.
14	2.5	.3	54	2.9	1.8	.3	1.2	1.2	.5	.6	.2	1.6	.1	.2	1:3.2	.6	.5	.04		2.3	2.0	3.8	2.7
14	4.5	.9	53	4.6	2.0	.4	1.8	1.8	1.2	.9	.5	2.4	.2	.2	1:3.0	.8	.7	.06		5.0	1.5	2.6	1.8
14	6.5	1.0	52	7.1	3.8	.7	2.9	2.7	2.1	1.4	.5	3.8	.3	.4	1:3.1	1.4	1.1	.09		5.5	1.4	3.8	2.7
14	8.5	1.3	52	9.0	4.1	.9	3.4	3.6	5.4	1.8	1.1	4.8	.5	.5	1:3.0	1.9	1.4	.12		6.0	1.2	4.3	3.2
14	10.5	1.9	52	10.8	5.8	.8	4.4	4.5	8.6	2.2	1.2	5.8	.6	.7	1:3.3	2.5	1.7	.14		8.7	1.0	3.7	2.8

CHICKS OF LOT II.—GROUP A.

RATION CONTAINING ANIMAL FOOD AND WITH LOW PERCENTAGE OF ASH.

14	2.5	.3	55	3.6	1.6	.3	1.2	1.2	.5		.7	1.8	.1	.2	1:3.0	.6	.5	.04	2.6	2.4	3.6	2.5
14	4.5	.6	54	3.9	2.4	.5	1.8	1.8	1.2		.4	2.4	.2	.2	1:2.9	.8	.7	.05	3.9	1.5	3.1	2.4
14	6.5	.8	53	6.8	3.3	.6	2.7	2.6	2.1		.7	3.6	.3	.4	1:3.0	1.3	1.0	.08	4.2	1.4	4.5	3.2
14	8.5	1.2	53	9.4	4.8	.9	3.8	3.9	5.3		.9	5.1	.5	.6	1:3.1	2.0	1.5	.12	5.7	1.4	4.7	3.4
14	10.5	1.8	52	12.4	6.2	1.3	4.8	4.7	8.6		1.3	6.8	.7	.7	1:3.0	2.7	1.9	.15	8.6	1.5	4.1	3.2

TABLE III.—CHICKS OF LOT III.—GROUP B.

RATION CONTAINING ANIMAL FOOD AND WITH LOW PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period.															Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
				Mixture 1.	Corn meal.	Blood meal.	Wheat	Cracked corn.	Alfalfa.	Florida rock.	Sand	Protein in food.	Ash in food besides rock.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
	Weeks	Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
14	3	.3	32	1.8	.7	.1	1.7	1.7	.9	5	.3	1.1	.1	.1	1:3.8	.5	.4	.03	1.1	1.8	5.6	4.0
14	5	.4	27	3.7	4.0	.7	3.2	1.7	1.8	1.0	.3	2.7	.2	.3	1:3.4	1.1	.8	.97	2.0	2.4	8.1	4.0
14	7	.8	25	5.8	3.0	.5	3.1	2.5	3.4	1.5	.9	3.2	.3	.4	1:3.2	1.3	1.0	.08	4.6	1.7	4.0	2.7
14	9	1.1	24	6.0	5.6	.7	3.8	3.3	5.8	1.5	.8	3.9	.4	.5	1:3.6	1.8	1.3	.10	5.4	1.4	4.3	3.3
14	11	1.5	24	9.5	8.2	1.5	5.9	5.0	9.3	2.4	.8	6.5	.7	.8	1:3.4	2.8	2.0	.16	6.6	1.5	5.6	4.2

CHICKS OF LOT IV.—GROUP B.

RATION CONTAINING ANIMAL FOOD AND WITH LOW PERCENTAGE OF ASH.

										Oyster shell.			Besides shell.									
14	3	.3	33	2.0	.9	.1	1.8	1.3	.8	.1	.3	1.2	.1	.2	1:3.7	.5	.4	.03	1.1	1.8	6.4	4.3
14	5	.3	31	3.5	3.0	.5	1.9	1.7	1.7	.2	.5	2.2	.2	.3	1:3.3	.9	.7	.05	1.3	2.3	9.6	5.8
14	7	.6	30	4.3	3.6	.6	3.2	2.7	3.3	.2	.5	2.9	.3	.4	1:3.6	1.3	.9	.07	4.2	1.9	3.9	3.1
14	9	.9	30	5.3	4.0	.7	2.9	2.0	5.6	.3	.7	3.4	.4	.4	1:3.2	1.5	1.0	.08	5.3	1.3	3.5	2.7
14	11	1.2	30	7.7	5.7	1.1	4.7	3.8	7.9	.7	1.0	5.0	.5	.6	1:3.3	2.2	1.5	.12	4.2	1.4	6.5	5.0

TABLE I.—COMPOSITION OF FOODS USED FOR GROUPS A AND B.

Food.	Water.	Ash.	Protein.	Fiber.	N-free extract.	Fat.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Mixture 1	13.8	1.7	31.3	1.9	49.5	1.8
Cracked corn	13.6	1.4	8.5	1.8	71.1	3.6
Wheat	16.6	1.7	12.6	2.2	65.1	1.8
Corn meal	14.6	1.4	8.1	1.9	70.4	3.6
Blood meal	11.0	3.0	85.1	?	.6	.3
Green alfalfa	77.7	2.0	3.7	6.0	9.9	.7

The foods used had the average composition shown in the accompanying table. The sand used was white glass sand 99.5 per ct. of silica. The raw Florida rock contained 2.8 per ct. of moisture and organic matter and 32.4 per ct. of phosphoric acid. The oyster shell contained about 3 per ct. of moisture and organic matter and over 94 per ct. of carbonate of lime.

RATIONS FOR GROUP C.

The lots of chicks V and VI were fed wheat, cracked corn, green alfalfa and a mixture (2) composed of six parts each of wheat middlings and Chicago gluten meal, 3 parts each of wheat bran and O. P. linseed meal, 5 parts of germ gluten meal and 10 parts of corn meal.

To the ration for each one ounce of sand was added for every 15 ounces of grain food. Lot V received in addition one ounce of Florida rock.

TABLE IV.—COMPOSITION OF FOODS USED FOR GROUPS C, D AND E.

Food.	Water.	Ash.	Protein.	Fiber.	N-free extract.	Fat.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pec ct.*
Mixture 2	13.9	2.9	20.3	4.5	53.4	5.0
Mixture 3	13.0	13.8	20.3	3.1	44.4	5.4
Cracked corn	17.2	1.2	9.1	1.3	67.5	3.7
Wheat	17.1	1.6	10.7	2.3	66.4	1.9
Green alfalfa	80.2	1.9	4.5	4.7	7.7	1.0

RATIONS FOR GROUP D.

Lots VII, VIII, IX and X received the same foods used for the two lots of group C in quite similar proportions. Sand in the proportion of 1 ounce to 10 ounces of grain was fed to lot VIII.

TABLE V.—CHICKS OF LOT V.—GROUP C.

RATION WITHOUT ANIMAL FOOD AND WITH MEDIUM PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period.													Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
				Mixture 2.	Cracked corn.	Wheat	Alfalfa.	Florida rock.	Sand.	Protein in food.	Ash in food besides rock.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
	Weeks	*Lbs.*		*Ozs.*	*Ozs.*	*Ozs*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*		*Ozs.*	*Ozs.*	*Cts.*	*Ozs.*	*Ozs.*	*Cts.*	*Lbs.*
14	3	.4	24	6.3	1.5	1.5	1.2	.6	.7	1.6	.2	.4	1:4.2	.7	.6	.04	2.2	1.9	4.6	3.4
14	5	.5	24	8.5	2.6	2.5	2.0	.8	.9	2.3	.4	.6	1:4.3	1.1	.8	.06	2.4	1.9	6.1	5.0
14	7	.7	24	9.1	2.7	3.3	3.8	.9	.9	2.6	.4	.6	1:4.4	1.3	1.0	.07	2.3	1.6	7.4	6.0
14	9	.9	24	13.7	2.3	1.7	4.7	1.4	1.4	3.4	.5	.9	1:3.9	1.6	1.1	.09	4.2	1.4	4.6	3.8
14	11	1.1	24	11.7	3.2	3.5	5.2	1.2	1.2	3.3	.5	.8	1:4.2	1.7	1.2	.09	2.8	1.2	7.2	5.9

CHICKS FOR LOT VI.—GROUP C.

RATION WITHOUT ANIMAL FOOD AND WITH MEDIUM PERCENTAGE OF ASH.

14	3	.4	24	6.0	1.4	1.3	1.2		.6	1.5	.2	.4	1:4.2	.7	.5	.04	2.5	1.7	3.6	3.0
14	5	.5	22	10.2	2.8	2.9	2.2		1.0	2.7	.4	.7	1:4.3	1.3	1.0	.07	3.4	2.1	4.9	4.1
14	7	.6	21	8.8	3.3	3.2	4.1		.9	2.6	.4	.7	1:4.4	1.4	1.0	.07	1.3	1.6	12.3	10.4
14	9	.9	21	16.2	2.3	2.5	5.3		1.6	4.0	.6	1.0	1:3.9	1.9	1.4	.10	4.1	1.7	5.4	4.6
14	11	.9	21	12.4	4.1	3.9	6.0		1.2	3.6	.6	.9	1:4.3	1.9	1.3	.10	.5	1.4		

TABLE VI.—CHICKS OF LOT VII.—GROUP D.

RATION WITHOUT ANIMAL FOOD AND WITH MEDIUM PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period. Mixture 2.	Cracked corn.	Wheat.	Alfalfa.	Sand.	Protein in food.	Ash in food.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.	Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
	Weeks	Lbs		Ozs.	Ozs.	Ozs.	Osz.	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
14	2	.2	46	4.5	1.0	1.0	.9		1.1	.2	.3	1:4.1	.5	.4	.03	.7	2.4	10.s	5.3
14	4	.2	41	4.9	1.5	1.0	2.4		1.4	.2	.3	1:4.2	.7	.5	.04	.5	3.1	15.3	9.7
14	6	.5	36	7.8	2.0	1.5	3.1		2.1	.3	.5	1:4.1	1.0	.7	.05	3.5	2.1	3.3	2.9
14	8	.7	34	12.5	2.8	2.3	4.9		3.3	.5	.8	1:4.1	1.6	1.1	.08	3.7	2.0	5.0	4.3
14	10	.9	34	19.7	4.3	3.4	6.2		5.0	.8	1.3	1:4.1	2.4	1.8	.13	3.7	2.1	7.7	6.6

CHICKS OF LOT VIII.—GROUP D.

RATION WITHOUT ANIMAL FOOD AND WITH MEDIUM PERCENTAGE OF ASH.

14	2	.2	48	4.3	1.0	1.0	1.0	.6	1.1	.2	.3	1:4.2	.5	.4	.03	.8	2.3	8.8	5.1
14	4	.3	43	5.0	1.4	.9	2.3	.7	1.3	.2	.3	1:4.1	.7	.5	.03	.7	2.0	11.0	7.7
14	6	.5	40	9.6	1.9	1.5	3.1	1.2	2.2	.3	.6	1:4.1	1.1	.8	.06	3.5	2.0	3.6	3.1
14	8	.8	40	11.6	2.6	2.1	5.2	1.7	3.1	.5	.8	1:4.1	1.5	1.1	.08	4.6	1.9	3.8	3.3
14	10	1.0	40	15.1	3.6	2.8	6.3	2.2	4.0	.6	1.0	1:4.1	2.0	1.4	.10	2.9	1.6	7.8	6.8

TABLE VII.—CHICKS OF LOT IX.—GROUP D.

RATION WITHOUT ANIMAL FOOD AND WITH MEDIUM PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period.													Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
				Mixture 2.	Cracked corn.	Wheat	Alfalfa.	Florida rock.		Protein in food.	Ash in food besides rock.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
	Weeks	Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
14	2	.2	48	4.1	1.0	.9	1.0	.6		1.1	.2	.3	1:4.1	.5	.4	.03	1.3	1.9	5.2	3.7
14	4	.3	48	5.1	1.3	.8	2.0	.7		1.3	.2	.3	1:4.1	.7	.5	.04	1.6	1.7	5.1	4.2
14	6	.6	43	9.8	2.3	1.9	2.9	1.4		2.5	.4	.6	1:4.1	1.2	.9	.07	5.0	1.9	3.1	2.5
14	8	.9	37	13.5	3.5	3.0	5.7	1.9		3.6	.6	.9	1:4.1	1.8	1.3	.10	3.7	1.7	6.0	5.0
14	10	1.2	37	17.9	3.8	3.2	6.8	2.5		4.6	.7	1.2	1:4.0	2.3	1.6	.12	4.3	1.5	6.4	5.2

CHICKS OF LOT X.—GROUP D.

RATION WITHOUT ANIMAL FOOD AND WITH MEDIUM PERCENTAGE OF ASH.

								Bone ash.	Oyster shell.		Besides bone ash and shell.									
14	2	.3	44	4.3	1.2	1.2	.9	.4	.2	1.2	.2	.3	1:3.1	.5	.4	.04	1.1	2.1	7.4	3.3
14	4	.4	37	6.8	1.6	1.0	2.6	.6	.3	1.7	.3	.4	1:4.1	.9	.6	.05	1.8	1.9	6.2	3.7
14	6	.7	33	13.1	3.0	2.6	3.4	1.2	.6	3.3	.5	.8	1:4.1	1.6	1.2	.10	4.9	2.1	4.5	3.3
14	8	.9	31	16.3	4.4	3.5	5.4	1.5	.8	4.3	.6	1.1	1:4.2	2.1	1.5	.13	3.9	1.9	7.7	5.6
14	10	1.2	30	22.6	4.0	3.5	7.0	2.2	1.1	5.6	.9	1.4	1:4.0	2.6	1.9	.16	2.6	1.8	14.3	6.8

TABLE VIII.—CHICKS OF LOT XI.—GROUP E.

RATION CONTAINING ANIMAL FOOD WITH HIGH PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	AVERAGE PER FOWL FOR PERIOD. Mixture 3.	Cracked corn.	Wheat.	Alfalfa.	Oyster shell.	Protein in food.	Ash in food besides shell.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.	Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
	Weeks	Lbs.		Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
14	2	.3	31	3.6	.6	1.3	1.3	.5	1.0	.5	.2	1:3.8	.5	.4	.03	1.6	1.6	4.7	3.1
14	4	.5	31	11.1	1.6	1.3	2.9	1.7	2.7	1.6	.7	1:3.5	1.2	.9	.09	3.5	2.3	5.5	3.6
14	6	.9	29	18.2	3.3	3.5	3.8	2.7	4.5	2.7	1.2	1:3.7	2.1	1.6	.15	6.3	2.2	5.3	3.3
14	8	1.4	29	21.7	4.4	4.0	6.9	3.3	5.5	3.2	1.5	1:3.7	2.6	1.9	.18	8.2	1.6	5.0	3.3
14	10	1.9	29	23.7	5.1	5.2	13.8	3.5	6.5	3.7	1.7	1:3.7	3.4	2.3	.21	6.3	1.4	7.2	5.1

CHICKS OF LOT XII.—GROUP E.

RATION CONTAINING ANIMAL FOOD WITH HIGH PERCENTAGE OF ASH.

								Sand.											
14	2	.3	31	4.5	1.3	1.4	1.3	.7	1.2	.7	.3	1:4.0	.6	.5	.03	1.9	1.8	3.9	3.3
14	4	.6	31	10.5	1.8	1.4	2.9	1.6	2.6	1.5	.7	1:3.6	1.2	.9	.07	4.7	1.9	3.2	2.7
14	6	1.0	31	16.2	2.9	3.3	3.5	2.4	4.1	2.4	1.1	1:3.7	1.8	1.4	.11	6.4	1.7	3.8	3.1
14	8	1.5	30	21.1	4.4	4.1	6.7	3.2	5.4	3.2	1.4	1:3.7	2.6	1.9	.14	7.5	1.5	4.2	3.2
14	10	2.0	30	22.7	4.5	4.6	13.3	3.4	6.1	3.5	1.6	1:3.7	3.2	2.1	.16	6.9	1.2	5.1	4.4

TABLE IX.—CHICKS OF LOT XIII.—GROUP E.

RATION CONTAINING ANIMAL FOOD WITH HIGH PERCENTAGE OF ASH.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period.												Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
				Mixture 3.	Cracked corn.	Wheat.	Alfalfa.	Protein in food.	Ash in food.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.					
	Wks.	*Lbs.*		*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*		*Ozs.*	*Ozs.*	*Cts.*		*Ozs.*	*Ozs.*	*Cts.*	*Lbs.*
14	2	.3	30	3.6	1.2	1.5	1.3	1.1	.6	.3	1:4.1	.5	.4	.03		1.4	1.6	5.3	3.7
14	4	.6	27	13.2	1.7	1.4	3.3	3.1	1.9	.8	1:3.4	1.4	1.0	.09		4.4	2.3	4.4	3.2
14	6	1.1	27	19.1	3.8	4.0	4.1	4.8	2.8	1.3	1:3.7	2.2	1.7	.14		7.7	2.1	4.1	3.1
14	8	1.6	27	22.6	4.7	3.7	7.4	5.7	3.4	1.5	1:3.7	2.7	2.0	.16		8.5	1.5	4.3	3.3
14	10	2.0	27	26.7	5.3	5.4	14.8	7.2	4.1	1.9	1:3.7	3.7	2.5	.20		6.8	1.4	6.6	5.2

In the food for lot IX was mixed the same proportion of Florida rock, and lot X was fed an equal proportion of a mixture of 2 parts of bone ash to one of ground oyster shell.

The Florida rock fed at this time contained 5 per ct. of water and organic matter and the oyster shell 3 per ct. The accompanying table shows the average composition of the foods used.

RATIONS FOR GROUP E.

A ration partly of animal food carrying much ground bone was fed to lots XI, XII and XIII. It consisted of wheat, cracked corn, green alfalfa and a mixture (3) of 7 parts corn meal, 6 parts animal meat, 4 parts wheat middlings and 3 parts wheat bran.

With every 28 ounces of dry food 3 ounces of ground oyster shell was also fed to lot XI and 3 ounces of sand to lot XII. The average analyses of foods used will be found in table IV.

RATIONS FOR GROUP F.

Lots XIV and XV received no animal food. The ration consisted of wheat, cracked corn, green alfalfa and a grain mixture of 5 parts each of wheat bran, pea meal and gluten meal with 4 parts each of linseed meal, malt sprouts, corn meal, wheat middlings and ground oats. With every 11 ounces of grain food 1 ounce of ground oyster shell was fed to lot XIV and 1 ounce of Florida rock to lot XV.

The accompanying table shows the average composition for the several foods:

TABLE X.—COMPOSITION OF FOODS USED FOR GROUPS F AND G.

Food.	Water.	Ash.	Protein.	Fiber.	N-free extract.	Fat.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Mixture 4	12.6	3.5	19.9	6.5	52.7	4.8
Wheat	15.2	1.6	10.7	2.1	68.7	1.7
Cracked corn	16.0	1.2	8.5	1.6	69.3	3.4
Alfalfa	52.1	4.1	7.8	12.0	22.6	1.4

RATIONS FOR GROUP G.

The same grain rations fed to the chicks of group F were also fed to lots XVI, XVII, XVIII and XIX. With every eleven ounces of grain food one ounce of sand was fed to lot XVI, one ounce of ground

TABLE XI.—CHICKS OF LOT XIV.—GROUP F.

RATION WITHOUT ANIMAL FOOD. PERCENTAGE OF ASH HIGHER THAN USUAL.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period.												Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
				Mixture 4.	Wheat.	Cracked corn.	Alfalfa.	Oyster shell.	Protein in food.	Ash in food besides shell.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.				
	Weeks	*Lbs.*		*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs*	*Ozs.*	*Ozs.*	*Ozs.*		*Ozs.*	*Ozs.*	*Cts*	*Ozs.*	*Ozs.*	*Cts.*	*Lbs.*
7	2	.2	54	1.7	.5	.2	.5	.2	.4	.1	.1	1:3.5	.4	.3	.03	.8	2.3	3.4	2.7
14	3	.3	76	4.9	1.2	.6	2.2	.6	1.3	.3	.3	1:4.2	.7	.5	.03	1.5	2.0	5.2	4.4
14	5	.4	76	6.3	1.6	.8	1.3	.8	1.6	.3	.4	1:4.3	.8	.6	.05	2.4	1.7	4.2	3.3
14	7	.6	73	10.4	2.6	1.3	3.1	1.3	2.7	.5	.6	1:4.2	1.3	1.0	.07	3.4	2.0	4.9	3.9
14	9	.9	70	15.7	3.9	2.0	3.8	2.0	4.0	.8	.9	1:4.2	1.9	1.5	.11	4.1	1.9	6.2	4.9
14	11	1.4	68	19.7	3.9	2.4	4.5	2.5	4.9	1.0	1.1	1:4.2	2.3	1.8	.13	6.8	1.5	4.4	3.3

CHICKS OF LOT XV.—GROUP F.

RATION WITHOUT ANIMAL FOOD. PERCENTAGE OF ASH HIGHER THAN USUAL.

								Florida rock.		Besides rock.									
7	2	.2	54	2.1	.5	.2	.5	.3	.5	.1	.1	1:4.2	.5	.4	.03	.9	2.5	3.4	2.7
14	3	.3	76	4.8	1.3	.6	1.3	.6	1.3	.2	.3	1:4.2	.6	.5	.03	2.1	1.8	3.7	3.0
14	5	.5	74	8.2	2.0	1.0	2.3	1.0	2.1	.4	.5	1:4.2	1.0	.8	.06	3.8	1.9	3.4	2.9
14	7	.8	71	10.2	2.6	1.1	3.1	1.3	2.6	.5	.6	1:4.2	1.2	1.0	.07	3.5	1.5	4.5	3.6
14	9	1.1	69	16.3	4.1	2.2	3.9	2.0	4.2	.8	1.0	1:4.2	1.9	1.5	.11	4.3	1.6	6.0	4.9
14	11	1.6	69	19.1	4.8	2.4	4.5	2.4	4.9	1.0	1.1	1:4.2	2.2	1.8	.13	5.8	1.3	5.1	4.3

TABLE XII.—CHICKS OF LOT XVI.—GROUP G.

RATION WITHOUT ANIMAL FOOD. PERCENTAGE OF ASH HIGHER THAN USUAL.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl for Period. Mixture 4.	Wheat.	Cracked corn.	Alfalfa.	Sand.	Protein in food.	Ash in food.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.	Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
	Weeks	*Lbs.*		*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*	*Ozs.*		*Ozs.*	*Ozs.*	*Cts.*	*Ozs.*	*Ozs.*	*Cts.*	*Lbs.*
14	1	.3	58	4.9	1.4	.6	.8	.6	1.2	.2	.3	1:4.2	.5	.4	.03	2.5	2.3	3.0	2.4
14	3	.4	56	7.4	1.8	.7	1.6	.9	1.9	.4	.4	1:4.2	.8	.7	.05	1.8	1.9	6.1	4.6
14	5	.5	53	9.9	2.5	1.5	2.4	1.2	2.5	.5	.6	1:4.3	1.2	.9	.07	1.7	2.1	8.9	6.9
14	7	.8	50	12.5	3.0	2.2	3.9	1.6	3.3	.7	.8	1:4.3	1.7	1.2	.09	4.3	1.9	4.5	3.7
14	9	1.1	50	14.3	3.7	1.2	5.0	1.8	3.7	.8	.9	1:4.2	1.7	1.4	.09	3.8	1.4	5.6	5.0
14	11	1.3	50	16.6	4.1	2.1	6.2	2.1	4.4	.9	1.0	1:4.2	2.1	1.6	.11	3.4	1.3	7.4	6.7

CHICKS OF LOT XVII.—GROUP G.

RATION WITHOUT ANIMAL FOOD. PERCENTAGE OF ASH HIGHER THAN USUAL.

								Oyster shell.		Besides shell.									
14	1	.2	58	4.2	1.4	.5	.8	.5	1.1	.2	.3	1:4.3	.5	.4	.03	1.6	2.7	4.4	3.2
14	3	.3	54	7.6	1.9	.7	1.7	1.0	1.9	.4	.4	1:4.2	.9	.7	.05	1.2	2.8	9.6	7.3
14	5	.5	48	9.9	2.3	1.5	2.6	1.2	2.5	.5	.6	1:4.3	1.2	.9	.07	1.1	2.3	13.9	8.2
14	7	.8	46	12.9	3.2	1.6	4.3	1.6	3.4	.7	.8	1:4.2	1.6	1.2	.09	2.0	1.9	10.6	8.9
14	9	1.1	45	16.1	4.2	1.9	5.6	2.0	4.2	.9	1.0	1:4.3	2.0	1.6	.12	4.7	1.6	5.5	4.4
14	11	1.4	45	18.0	4.4	2.4	6.8	2.3	4.8	1.0	1.1	1:4.3	2.3	1.8	.13	5.7	1.4	5.1	4.3

TABLE XIII.—CHICKS OF LOT XVIII.—GROUP G.

RATION WITHOUT ANIMAL FOOD. PERCENTAGE OF ASH HIGHER THAN USUAL.

No. of days in period.	Age of chicks at beginning of period.	Average wt. of chicks at end of period.	No. of chicks.	Average per Fowl per Period. Mixture 4.	Wheat.	Cracked corn.	Alfalfa.	Florida rock.	Protein in food.	Ash in food besides rock.	Fats in food.	Approximate nutritive ratio.	Total food per day.	Dry matter in food per day.	Cost of food per day.	Average gain in wt. per chick during period.	Dry matter in food per day for each pound live wt. fed.	Cost of food for each pound gain in wt.	Dry matter in food for each pound gain in wt.
	Weeks	Lbs.		Ozs.	Ozs.	Ozs.	Ozs	Ozs.	Ozs.	Ozs.	Ozs.		Ozs.	Ozs.	Cts.	Ozs.	Ozs.	Cts.	Lbs.
14	1	.3	58	4.4	1.2	.6	.8	.5	1.1	.2	.3	1:4.3	.5	.4	.03	1.9	2.1	3.8	3.0
14	3	.4	53	7.7	2.0	.6	1.7	1.0	1.9	.4	.4	1:4.2	.9	.7	.05	1.9	2.0	6.3	4.9
14	5	.6	51	8.6	2.1	1.3	2.5	1.1	2.2	.4	.5	1:4.3	1.0	.8	.06	2.9	1.7	4.7	3.8
14	7	.9	48	12.9	3.1	1.7	4.1	1.6	3.4	.7	.8	1:4.3	1.6	1.2	.09	4.6	1.6	4.4	3.7
14	9	1.1	47	15.6	3.8	1.9	5.4	1.9	4.1	.8	.9	1:4.2	1.9	1.5	.11	3.4	1.5	7.1	5.6
14	11	1.4	47	18.6	4.6	2.3	6.5	2.3	4.9	1.0	1.1	1:4.2	2.3	1.8	.13	4.0	1.4	7.3	6.3

CHICKS OF LOT XIX.

RATION WITHOUT ANIMAL FOOD. PERCENTAGE OF ASH HIGHER THAN USUAL.

								Bone ash and oyster shell.		Besides bone ash and shell.									
14	1	.3	58	4.3	1.2	.5	.8	.5	1.1	.2	.3	1:4.3	.5	.4	.03	2.1	2.0	3.4	2.5
14	3	.4	53	7.9	1.8	.7	1.7	1.0	2.0	.4	.5	1:4.1	.9	.7	.06	2.0	2.0	6.4	4.4
14	5	.6	50	8.6	2.3	1.5	2.5	1.1	2.3	.5	.5	1:4.3	1.1	.8	.07	2.7	1.7	5.6	3.9
14	7	.9	44	14.3	3.5	1.8	4.4	1.8	3.7	.8	.9	1:4.2	1.7	1.4	.11	4.1	1.8	5.8	3.6
14	9	1.3	43	17.2	4.2	2.0	5.9	2.1	4.5	.9	1.0	1:4.2	2.1	1.6	.13	5.4	1.5	5.4	4.3
14	11	1.6	43	19.9	4.9	2.6	7.2	2.5	5.3	1.1	1.2	1:4.3	2.5	1.9	.15	4.4	1.3	7.6	6.2

oyster shell to lot XVII, one ounce of Florida rock to lot XVIII and one ounce of a mixture of equal parts of bone ash and oyster shell to lot XIX.

RESULTS FOR EACH GROUP.

GROUP A.

The grains and blood meal fed to lots I and II gave a ration rather low in mineral matter. About 2 per ct. of the total dry matter was ash during the first four weeks. It was somewhat more afterward. The average for the whole time was about 2.2 per ct. With the addition of Florida rock the amount of mineral matter was 10.3 per ct. of the total dry matter in the food for lot I.

About 30 per ct. of the protein in the ration came from animal food. This percentage was slightly higher during the first four weeks than afterward. On the average for the ten weeks lot I made a pound gain in weight for every 2.7 pounds of dry matter in the food, exclusive of Florida rock; and lot II one pound gain for every 3.0 pounds of dry matter. The cost of food, including that of rock, (the rock cost about 22 per ct. as much as the animal food) per pound gain was 3.7 cents for lot I and 4.1 cents for lot II. The average weight attained was greater for lot I.

GROUP B.

The ration, similar to that for group A, fed to lots III and IV supplied ash constituents amounting to 2.1 per ct. of the total dry matter during the first four weeks and about 2.4 per ct. afterward. Nearly 30 per ct. of the protein was derived from animal food.

The total mineral matter with addition of the ground rock formed 10.1 per ct. of the dry matter in the food, and with addition of ground shell 4.6 per ct. The smaller amount of ground oyster shell was used to avoid the ill effects which usually followed the feeding of a large amount.

The amount of dry matter in the food, exclusive of the added mineral matter, for each pound gain in weight was 3.6 pounds

with lot III and 3.8 pounds with lot IV. The food cost of gain including cost of rock and shell was 5.2 cents for lot III and 5.1 cents for lot IV. More food was eaten by lot III, growth was faster, and greater average weight was attained.

GROUP C.

The percentage of ash constituents supplied by the food to this group was not unusually high nor very low, being about 3.1 per ct. of the dry matter. With the Florida rock added about 9.8 per ct. of the total dry matter in the food for lot V was mineral. By this lot about 4.7 pounds of total dry matter, exclusive of rock, was required for each pound gain in weight and 5.5 pounds was required by lot VI having sand and no rock. The food cost (including rock) for lot V was 5.8 cents per pound gain and for lot VI 7.1 cents. Somewhat less food was consumed by lot V and a greater growth made.

GROUP D.

In the rations for lots VI, VII, VIII and IX the ash constituted from 3.1 to 3.3 per ct. of the total dry matter, not a low percentage for a grain ration. With the ground rock added for lot IX the mineral matter was 12.7 per ct. and with the bone ash and shell for lot X the mineral matter was 12.9 per ct. of the total dry matter.

The results favored lot IX having the Florida rock. The net gain in weight was greatest and the least amount of food was required for each pound gained. The weight per fowl at the end was considerably greater than for lots VII and VIII. In the average weight attained lot X was not surpassed. This lot, however, was alone favored by a larger proportion of male chicks. More checks died in lot X than in any other (many of the chicks lost from these lots were killed by rats). The results from lot VIII having sand added to the food were better than from lot VII having none; and the net results were better than from lot X

because of lower mortality, although the average growth of surviving chicks was better in lot X.

On the average for the whole period the amount of dry matter in the food, exclusive of added mineral matter, for each pound gain in weight was 5.0 pounds for lot VII, 4.5 pounds for lot VIII, 4.0 pounds for lot IX and 4.6 pounds for lot X. The food cost, including added mineral matter, per pound gain was 6.2 cents for lot VII, 5.4 cents for lot VIII, 4.9 cents for lot IX and 7.4 cents for lot X.

GROUP E.

The lots XI, XII and XIII of this group had food rich in mineral matter, about 85 per ct. of which came from animal meal containing much bone. About 44 per ct. of the protein in the ration came from animal food. The ash constituents represented about 11.8 per ct. of the total dry matter in the food. With the added oyster shell for lot XI they represented nearly 21 per ct.

The best results came from lot XII having sand mixed in their food. The advantage over those having none (lot XIII) seemed greatest during the first four weeks. Although the average growth made was no greater, less food was required for it, the mortality was lower and the net results were better.

The dry matter in the food consumed, exclusive of oyster shell, for each pound gain in weight was 3.8 pounds for lot XI, 3.4 pounds for lot XII and 3.7 pounds for lot XIII. The food cost per pound gained was 5.7 cents for lot XI, 4.1 cents for lot XII and 4.9 cents for lot XIII.

GROUP F.

The supply of mineral matter in the food for lots XIV and XV was somewhat greater than is usual in an entire grain ration. The ash constituted about 3.9 per ct. of the total dry matter. With the added oyster shell for the one lot the total mineral matter was raised to 12.1 per ct., and with the Florida rock for the other to 11.8 per ct. of the total dry matter.

There was practically no difference in the relation of food to increase in weight for the two lots. By both a pound gain was made for every 3.9 pounds of dry matter in the food. The average growth was greater for the lot having Florida rock and the food cost of net gain was less, being about 5.1 cents and 4.8 respectively.

GROUP G.

Practically the same basal ration fed to the chicks of this group that was fed to the former group supplied ash constituents to the extent of 4 per ct. of the dry matter. The amount of mineral matter was raised to 12.1 per ct. by the addition of oyster shell for lot XVII and to 12.2 per ct. of the total dry matter for lot XVIII by the addition of Florida rock, and to the same proportion for lot XIX by bone ash and oyster shell.

The most rapid growth was made by the lot having bone ash and shell mixed with the food and less food was required per pound gain. The lot having Florida rock made a better growth than those having sand and a slightly better use of the food, although there was not great difference between these two lots. Poorer results accompanied the use of oyster shell in the food. More food was required by this lot per pound gain, and more chicks died. The equally large loss in pen XIX was not in so large part from disease. The dry matter in the food, exclusive of added mineral matter, for each pound gain was 5.3 pounds for lot XVII, 4.7 pounds for lot XVI, 4.6 pounds for lot XVIII and 4.2 pounds for lot XIX. The total food cost per pound gain was 6.8 cents for lot XVII, 5.8 cents for lot XIX and 5.6 cents for lots XVI and XVIII.

IN CONCLUSION.

In earlier feeding experiments with chicks, the addition of bone ash to rations not rich in mineral matter proved beneficial. By supplying the lack of mineral matter in this way, rations wholly of vegetable origin, arranged with due regard to palatability,

were made equal in efficiency to rations containing much animal food, although these latter had proved superior to ordinary grain rations.

In the experiments here reported a mixture of bone ash and oyster shell was used less profitably owing to the injurious effect of the ground shell though growth was increased by the addition of the mineral matter.

Compared with the use of an equal amount of sand in rations without animal food the mixture of ash and shell in two trials resulted in considerably more rapid growth. In one the use of food was much more efficient and in the other nearly as efficient; although the losses attributed to the use of shell made the feeding less profitable.

A ration without animal food and a ration including considerable animal food were rendered less efficient and less healthful by the admixture of powdered oyster shell than they were when mixed with an equal amount of sand.

Two rations without animal food and one ration having considerable with a little sand, gave much better growth, which was made on the whole with less food, when mixed with Florida rock phosphate than when mixed with ground oyster shell.

The mixing of ground rock phosphate in two rations without animal food resulted in more efficient use of food and more rapid growth than the mixing of sand alone.

The addition of the rock phosphate and sand to a ration containing considerable animal food, low in ash and to another ration without animal food resulted in better growth and more efficient use of food than the addition of sand alone.

The sand was mixed with the food, both in a ration without animal food and one containing animal food with bone; more efficient use of food resulted than when no sand was used. Not much greater average weight was attained but the chicks were healthier.

COMMENTS.

While these experiments show that there is often an advantage in feeding inorganic phosphates, even from such unusual material as ground rock, with rations containing sometimes more than the average amount of mineral matter, they are not quoted as recommending the general use of bone ash and Florida rock for feeding. Their chief value is in helping to better plan and interpret other experiments. Fine raw or cooked bone is better material for supplying a lack of phosphorus and lime, and more profitable to use, in part because of the associated organic matter.

The mixing of finely ground oyster shell in the food of chicks except in very small quantity has always resulted in an unthrifty condition and sometimes disease and death. At other times the use of a small amount of coarser material has not appeared injurious and it seems sometimes of benefit. It seems probable that injury comes from too rapid or too nearly complete neutralization of necessary acids in some digestive fluids.

The fact that the mixing of sand in the food proved an advantage, even for chicks running all day over sand, emphasizes the importance of looking after the supply of grit. But it is not profitable to buy poultry foods in which sand has been mixed. Sand or other grit can be obtained more cheaply.

REPORT

OF THE

Department of Bacteriology.

H. A. Harding, *Dairy Bacteriologist.*

[1]J. F. Nicholson, *Assistant Bacteriologist.*

[2]M. J. Prucha, *Assistant Bacteriologist.*

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[1] Resigned July 21, 1903.
[2] Appointed September 14, 1903.

REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

THE ROLE OF THE LACTIC-ACID BACTERIA IN THE MANUFACTURE AND IN THE EARLY STAGES OF RIPENING OF CHEDDAR CHEESE.*

H. A. HARDING.

SUMMARY.

1. Lactic-acid bacteria are always present in factory milk.

2. These lactic-acid bacteria check the growth of other forms by breaking up the sugar into acid and finally make up more than ninety per ct. of the total number of germs present in the milk and cheese.

3. The acid formed by these bacteria hastens the curdling action of the rennet.

4. This acid combines with paracasein to form at least two different compounds—paracasein monolactate and paracasein dilactate. The paracasein monolactate is normally formed in large quantities.

5. This formation of acid is necessary to the activity of the rennet pepsin.

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*A reprint of Bulletin No. 237.

INTRODUCTION.

As soon as American cheddar cheese and its method of manufacture were studied from a biological standpoint it was found that acid-forming bacteria thrive in the curd to such an extent as to make up more than 90 per ct. of the total flora of the cheese. It was natural to assume that the growth of this large number of bacteria, amounting to some millions in each gram of the curd, could not fail to have an influence upon the final result which we speak of as ripened cheese. Students of the problem have even gone so far as to hold that the lactic-acid bacteria are the principal, if not the only, cause of cheese ripening.

Scientific opinion is by no means unanimous as to the causes which bring about the ripening of cheese. Two other theories aside from the one just mentioned are supported by considerable evidence. According to certain students the ripening is brought about by a different class of bacteria characterized by the elaboration of enzymes capable of attacking and dissolving the coagulated casein. A third explanation assumes that the breaking down of the casein is largely due to the activity of enzymes secreted by the cow with the milk.

These wide differences of opinion concerning a problem which has been so long an object of study are the result of our inability to follow the changes going on within the cheese mass. While the problem is essentially one of applied biology, an exact knowledge of physiological chemistry, coupled with a proper appreciation of commercial quality is necessary for its solution. Since a sufficient knowledge of these three lines of human effort was not possessed by one man the study of the cause of the ripening of cheese was assigned by the Station Director to the coöperative activity of the Dairy Expert, the Chemist and the Bacteriologist. As a result of this coöperative effort a considerable advance has been made in our understanding of the problem of cheese ripening and results on a number of points have already

been published.[1] In this bulletin, while the author accepts the responsibility for all conclusions drawn from the data, he takes pleasure in acknowledging the important activities of his colleagues in planning and executing the experiments.

Recognition should be given to the work of Mr. L. A. Rogers who, as Assistant Bacteriologist during a portion of the investigation, had charge of the routine bacteriological examinations. Since his transfer to the Department of Agriculture at Washington his part of the investigation has been carried on by his successor, Mr. J. F. Nicholson.

ROLE OF LACTIC-ACID BACTERIA.

LACTIC-ACID BACTERIA ARE CONSTANTLY PRESENT IN FACTORY MILK.

Everyone knows that fresh milk left in a warm room sours rapidly and nearly everyone knows that this souring is due to the formation of acid by bacteria. Since milk drawn with certain precautions does not undergo this rapid souring it is plain that these bacteria find their way into the milk after it is drawn.

Because the acid formed during this souring process is principally lactic these various acid-forming species were early spoken of collectively as the lactic-acid bacteria. Without knowing exactly why, it was found that the formation of acid by these germs was a necessary part of the manufacture of cheddar cheese and in order to insure the presence and activity of the most desirable kinds it has long been the custom to begin the process of manufacture by adding considerable quantities of so-called " starter."

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[1] Van Slyke, L. L., Harding, H. A., & Hart, E. B. A Study of Enzymes in Cheese. N. Y. Agr. Exp. Station Bul. 203. (1901.)
Van Slyke, L. L., & Hart, E. B. A Study of Some of the Salts Formed by Casein and Paracasein with Acids. N. Y. Agr. Exp. Station Bul. 214. (1902.)
Van Slyke, L. L., & Hart, E. B. Methods for the Estimation of Proteolytic Compounds Contained in Cheese and Milk. N. Y. Agr. Exp. Station Bul. 215. (1902.)
Van Slyke, L. L., & Hart, E. B. Some of the Compounds Present in American Cheddar Cheese. N. Y. Agr. Exp. Station Bul. 219. (1902.)
Van Slyke, L. L., & Hart, E. B. Relation of Carbon Dioxide to Proteolysis in the Ripening of Cheddar Cheese. N. Y. Agr. Exp. Station Bul. 231. (1903.)
Van Slyke, L. L., Harding, H. A., & Hart, E. B. Rennet-Enzyme as a Factor in Cheese-Ripening. N. Y. Agr. Exp. Station Bul. 233. (1903.)
Van Slyke, L. L., & Hart, E. B. Conditions Affecting Chemical Changes in Cheese-Ripening. N. Y. Agr. Exp. Station Bul. 236. (1903.)

This starter is simply milk containing rapidly multiplying acid-forming bacteria, and while the small amount of acid already formed is useful in quickening the action of the rennet the principal effect of a starter lies in the increased activity of the germs.

Thus, partly as the result of natural causes and partly because of the action of the maker, the milk from which cheese is made is normally well seeded with these lactic-acid bacteria. As these germs are present in the factory milk in such large numbers it is but natural that they should pass over into the cheese.

THE GROWTH OF LACTIC-ACID BACTERIA CHECKS THAT OF OTHER FORMS IN THE MILK.

Conn & Esten[2] recently published the results of a careful study of the bacteria present in fresh milk and the rate at which the various kinds develop as the milk becomes older. Up to the time the milk is sour practically all the species of bacteria present in it continue to multiply, although as the latter stage is approached the germs other than the lactic-acid group increase more and more slowly. Very few lactic-acid bacteria are found in the fresh milk but they increase rapidly and in 12 to 18 hours at 20° C. (68° F.) they usually outnumber all those of the other kinds. At the higher temperature to which the milk is commonly exposed during the warmer portions of the summer the growth of all the bacteria is accelerated, and consequently at such times the lactic-acid bacteria more quickly make their presence felt. At the time of souring the acid bacteria commonly make up more than 95 per ct. of the total number.

While this problem has never before been so carefully studied from the biological standpoint the fact that an abundant growth of lactic-acid bacteria in milk checks the activity of other forms has long been known and utilized in cheese-making. It is a matter of common experience that the effect upon the cheese of various objectionable fermentations in the milk can be modified and often removed by the addition of liberal amounts of a vigorous lactic-acid starter in the cheese vat.

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[2] Conn & Esten. Ann. Rept. Storrs Exp. Station, **14**:13. (1901.)

THIS CHECKING IS DUE TO THE CHANGE OF SUGAR INTO ACID.

The ability to form acid, as the name implies, is the point of similarity upon which the classification of the lactic-acid group is based. Shirokich[3] has shown that when representatives of this group were grown in milk the nitrogenous portion was not attacked to a measurable extent. Chodat & Hoffman-Bang[4] analyzed milk cultures of five lactic-acid organisms and found that at the end of five weeks the milk sugar had decreased 1 to 1.25 per ct. A considerable portion of this sugar was converted into acid. While the larger part of this acid was believed to be lactic they determined the presence of small quantities of formic, valeric and acetic acids.

The destruction of this amount of sugar does not measure the limit of the ability of the germs to attack the sugar but rather shows the limit of the ability of the compounds present to dispose of the acid as formed. In similar milk cultures to which chalk had been added to combine with the excess of acid as formed, all of the 5.77 per ct. of sugar had disappeared in four of the five flasks at the end of five weeks.

The majority of organisms aside from this group prefer a neutral or even faintly alkaline reaction, while the lactic-acid organisms grow best in a slightly acid reaction. As soon, therefore, as they break up an appreciable quantity of sugar into acid they place their competitors in the milk at a disadvantage and this disadvantage increases with the increased formation of acid.

THE EFFECT OF THIS ACID UPON THE CURDLING ACTION OF THE RENNET.

The direct relation between the extent of acid formation and the rate of rennet action is well known. This fact is taken advantage of in practical cheese-making by the addition of partially soured starters to sweet milk in order to quicken the rate of coagulation. The effect of these starters is twofold. They have an immediate effect due to the acid which has already been formed and a later effect due to the increased rate at which the sugar of the milk is changed to acid.

[3] Schirokich. *Ann. Past.*, **12**:400. (1898.)

[4] Chodat & Hoffman-Bang. *Ann. Past.*, **15**:37. (1901.)

The effect of acid formation upon the action of the rennet may be directly observed by adding measured amounts of acid to milk and noting the decrease in the time required to curdle portions of the same with rennet.

In the following experiment $12\frac{1}{2}$ litres (25 pounds) of milk was used. The time required for the action of the rennet according to the Monrad rennet test was determined at the beginning of the experiment and after the addition of successive portions of acid, 100 cc. ($3\frac{1}{3}$ oz.) of the milk being used in each rennet test. Before each test, after the first, 2.5 cc. (1-12 oz.) of chemically pure lactic acid diluted with 100 cc. of water was added to the milk.

TABLE I.—EFFECT OF ACID UPON THE CURDLING ACTION OF THE RENNET.

Acid added.	Total acid added.	Monrad test.	Shortening of test.
Cc.	*Cc.*	*Seconds.*	*Seconds.*
0	0	225	
2.5	2.5	122	103
2.5	5.0	78	44
2 5	7.5	63	16
2 5	10.0	47	15
2.5	12.5	43	4

From this it is clearly seen that the addition of acid quickens the rate of curdling by rennet since the addition of 12.5 cc. of acid (about 0.1 per ct.) shortened the time of curdling from 3 minutes 45 seconds to 43 seconds. In other words the addition of 0.1 per ct. of acid to fairly sweet milk changed it as much as is allowable for milk intended for cheese-making.

This should help to emphasize the importance of delivering milk intended for cheese-making before the bacteria in it form any considerable quantities of acid.

It is also interesting to observe how much more noticeable is the effect from the first addition of acid. Here the time of curdling was shortened 1 minute 43 seconds, while the addition of an equal amount of acid at the close of the experiment shortened the time of curdling but 4 seconds. This is quite in accord with factory experience where the addition of sour milk has an immediate effect upon the rate of rennet action although the acid added amounts to only a very insignificant proportion.

THIS ACID COMBINES WITH THE CASEIN IN A DEFINITE WAY.

In the experiment by Chodat & Hoffman-Bang already referred to, which was a modification of an earlier experiment by von Freudenreich,[5] it was shown that, in the presence of chalk to combine with the acid, these germs were able to break down all the sugar. That a similar fixation of acid takes place during the manufacture and ripening of cheese is rendered probable by the rapidity with which the sugar is broken down during the process.

Sugar determinations made by Hart showed that in one instance shortly after the curd was cut the whey contained 4.75 per ct. of sugar while the whey obtained at the time the curd was ready for the press contained but 1.83 per ct. The destruction of the sugar which is left in the curd continues steadily and the sugar disappears from the cheese after a few days at ordinary curing temperatures. In spite of this destruction of sugar with its accompanying formation of acid the presence of free lactic acid in cheese has never been satisfactorily demonstrated.

In connection with this work upon cheese ripening Van Slyke and Hart have studied two compounds of acid with casein (or paracasein) and have described their chemical properties in Bulletin No. 214 of this Station.

The more important of these two compounds from the standpoint of our present knowledge of cheese ripening is an unsaturated combination of paracasein and acid called paracasein monolactate. This compound can be formed from paracasein in large quantities in the presence of dilute acid and is a compound constantly present during the process of cheese-making and ripening. This compound is insoluble in water but is soluble in dilute solutions of common salt (NaCl). Prepared in a fairly pure comdition this compound draws out in fine threads when applied to a hot iron. It seems that this well known "hot iron" test of the progress of acid formation has thus received a satisfactory explanation.

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[5] von Freudenreich. *Cent. f. Bakt.*, II Abt. **3**:231. (1897.)

A second salt of paracasein and acid called paracasein dilactate is formed from the monolactate by treating the latter with more acid. This compound is insoluble both in water and in dilute salt solutions and as yet little is known as to either its chemical properties or the part which it plays in cheese-ripening.

PARACASEIN MONOLACTATE IS FORMED IN CHEESE CURD BY LACTIC-ACID BACTERIA.

In order to determine whether paracasein monolactate could be formed in cheese through the activity of lactic acid organisms the following experiment was carried out.

Fresh milk was curdled by rennet in the presence of ether to prevent acid formation and after the moisture had been satisfactorily expelled from the curd the whey was drawn and the curd washed in three changes of warm water to remove the major part of the sugar and the water soluble compounds. The resulting mass contained 0.3 per ct. of sugar and about 4 per ct. of salt-soluble compounds.

Two series of flasks were prepared, each flask containing 50 cc. of water and 25 grams of curd ground with sand (922 mgs. nitrogen). These flasks were sterilized in steam for 10 minutes at 120° C. After cooling, Series I received an inoculation from a pure culture of an acid-forming bacillus agreeing closely with the description of *Bacillus lactis aerogenes.* Series II received an inoculation from the same organism and in addition 0.5 grams of sterile lactose in each flask. A similar sterile flask received neither sugar nor organism but 0.5 cc. of chemically pure lactic acid. Two flasks of each series were taken at each analysis. Bacteriological examinations of the flasks at the time they were taken for analysis indicated that they were free from contamination. The amount of nitrogen insoluble in water but soluble in a 5 per ct. solution of sodium chloride at the end of various intervals expressed in percentage of the total nitrogen is given in the following table.

TABLE II.—PARACASEIN MONOLACTATE FORMED IN CHEESE CURD BY BACTERIA AND BY ACID.

Date.	Lactic-acid bacteria.		Sterile.
	No lactose.	.5 gm. lactose.	.5 cc. lactic acid.
	Per ct.	*Per ct.*	*Per ct.*
Feb. 21—Initial.......	3.90 4.34	3.90 4 34	3.90 4.34
March 24............	3.52 4.07	40.65 28.46	44.72
May 22...............	2.71 2.98	20.87 17.89	
Aug. 15	2.98 2 71	8.94 8 94	

It is seen from this table that in the presence of cheese curd containing but a trace of sugar this organism was not able to form measurable quantities of salt-soluble material.

On the other hand the addition of lactose to similar flasks resulted in the formation of considerable amounts of the salt-soluble compound.

That the formation of this monolactate is really due to the transformation of sugar into acid is rendered probable by the action of the corresponding amount of lactic acid upon the sterile curd.

THE AMOUNT OF PARACASEIN MONOLACTATE IN MILK AND CHEESE.

While it is supposed that compounds of acid and casein are formed in the milk their measurement in this medium is beset with difficulties. However, the presence and amount of mono-salt in cheese curd can be determined in a fairly satisfactory manner.

In connection with the determination of sugar at different stages in the cheese-making process previously mentioned the amount of paracasein monolactate in the curd was estimated. Shortly after the cutting of the curd, when the milk sugar in the whey amounted to 4.75 per ct., there was but 5 per ct. of this salt-soluble compound in the curd; while at the time the curd was ready for the press, when the sugar in the whey had fallen to 1.83 per ct., the salt-soluble material in the curd had risen to 31.7 per ct. In normal cheddar cheese from one-half to three-fourths of

the nitrogen is found in the form of paracasein monolactate during the first week after the cheese is made.

From the table on page 71 it is seen that in the breaking down of ½ gram of lactose about one-third of the nitrogen in the 25 grams of curd was changed into the monosalt. This indicates that the breaking down, by bacteria, of sugar amounting to more than two per ct. of the fresh curd is necessary in order to account for the formation of the usual amount of monosalt in cheese.

RESULT OF TOO GREAT FORMATION OF ACID.

Flasks containing 50 cc. of water and 25 grams of the same cheese curd used in the preceding experiment were sterilized in steam at 120° C. Each of a series of these flasks received 1 gram of sterile lactose and was inoculated with the same culture of lactic-acid bacteria which had been used in the preceding experiment. Additional sterile flasks received 1 cc., 1.5 cc., and 2 cc. of chemically pure lactic acid but were not inoculated with bacteria. Bacteriological examinations made in connection with each analysis showed that the lactose series contained but the single species of bacteria with which it had been inoculated while the sterile flasks to which acid had been added remained sterile. The amount of nitrogen insoluble in water but soluble in a 5 per ct. solution of sodium chloride at the end of various intervals expressed in percents of the total nitrogen is given in the following table.

TABLE III.—PARACASEIN MONOLACTATE FORMED IN CHEESE CURD BY BACTERIA AND BY ACID.

Date.	Lactic-acid bacteria	Sterile flasks and chemically pure lactic acid		
	1 gm. lactose.	1 cc.	1.5 cc.	2 cc.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
February 21—Initial	3.90 4.34	3.90 4.34	3.90 4.34	3.90 4.34
March 10	23.31 20.60			
March 24	9.76 7.32	....	1.62	
May 22	3.52 3.25	2.17	2.16	
August 15	3.25 3.52	2.93	....	1.95

From the above results it would seem that 1 cc. or more of lactic acid to 25 grams of curd (or 4 per ct.) was too great an amount for the existence of paracasein monolactate.

In the flasks containing the bacteria and 1 gram of lactose we are able to follow in some detail the results of the gradual formation of a large amount of acid. On March 10 a considerable portion of the sugar in these flasks was yet untouched and about $\frac{1}{5}$ of the nitrogen was present as the monosalt. Two weeks later the sugar had nearly disappeared and less than 1-10 of the nitrogen remained in the salt-soluble form. By May 22 all the sugar had disappeared and the amount of monolactate had fallen to a very low figure where it remained August 15.

From these two experiments it seems fair to conclude that in forming the amount of monolactate ordinarily present in cheese the bacteria use up an amount of sugar equal to more than 2 per ct. and less than 4 per ct. of the cheese mass.

THE PRACTICAL OBJECTION TO TOO MUCH ACID.

The formation of acid is an unavoidable and apparently a necessary step in our present method of making cheddar cheese. However, the amount of acid which is really needed is small and is very easily exceeded to the detriment of the product. The exact extent to which the development of acid is desirable varies considerably, depending upon the temperature of curing and the market for which the cheese is intended, but in general the formation of acid is carried to the point where there is a decided mellowing of the curd. Whenever the formation of acid is carried much beyond this point the curd rapidly becomes plastic and refuses to part with the whey still contained within it.

Put to press in this condition the sugar contained in the excess of whey is broken down to acid, changing the curd from the plastic condition into a tough, resistant mass with a distinct acid odor. With this change in consistency the whey is set free and runs out upon the shelves. The ripening processes of such cheese are commonly retarded and the resulting flavor is bad.

LACTIC-ACID BACTERIA ARE NUMEROUS AND ACTIVE IN CHEESE.

It is but natural that very many of the lactic-acid bacteria which are present in the factory milk should pass over into the

cheese curd. Here the presence of the acid reaction resulting from the breaking up of sugar gives them an advantage over their competitors and this advantage is increased by the continued breaking down of the sugar contained in the curd.

The earliest attempt at determining the number of bacteria of different kinds present in ripening cheese by Adametz[6] showed that in both emmenthaler and backstein the lactic acid group included by far the larger part of the individuals. The work of von Freudenreich[7] on emmenthaler cheese has emphasized the fact that during the ripening period of this cheese there are few but lactic bacteria present. Russell & Weinzirl[8] showed that while a considerable number of liquefying bacteria was present in the milk at the time the rennet was added this group suffered a marked decline during the curing, while the lactic-acid germs flourished, especially during the first few weeks of the life of a cheddar cheese.

In a recent article Babcock, Russell, Vivian & Hastings[9] have demonstrated in detail that the ability of lactic-acid bacteria to displace the other forms in cheese depends primarily upon the action of these germs upon the milk sugar. When the milk sugar was largely removed from the fresh curd by repeatedly washing it with warm water the liquefying bacteria were abundant in the resulting cheese and this cheese differed markedly from the normal in its physical and chemical properties. In a duplicate portion of this washed curd in which the sugar was artificially replaced, this increase in the number of liquefying germs was prevented and this cheese did not differ widely from the normal in its flora or in its physical or chemical properties. The most evident difference between the normal cheese and that made from washed curd with the subsequent addition of sugar lay in the failure of the latter to reproduce exactly the normal cheese flavor.

When considering the flora of cheese, interest is commonly so centered upon this striking increase in the lactic forms that the

[6] Adametz. *Land. Jahrb.*, **18**:227. (1889.)
[7] von Freudenreich. *Cent. f. Bakt.*, II Abt., **1**:168. (1895.)
[8] Russell & Weinzirl. *Cent. f. Bakt.*, II Abt., **3**:456. (1897.)
[9] Babcock, Russell, Vivian & Hastings. Ann. Rept. Wis. Station, **18**:162 (1901.)

presence of other organisms is usually overlooked. It should not be forgotten that while the number of liquefiers rarely amounts to more than one per ct. of the total during the early history of the cheddar cheese, even under these circumstances their number is considerable. It is also not unreasonable to suppose that an enzyme formed by this class of organisms will continue to act in the cheese even after the disappearance of the living cells. The long-continued presence of this small number of liquefying organisms in the case of a 28-pound cheddar cheese is well illustrated by the following determinations made by Nicholson.

TABLE IV.—BACTERIA PER GRAM IN A RIPENING CHEDDAR CHEESE.

Age in days.	2.	4.	6.	21.	30.
Total number ..	13,582,000	18,990,000	17,387,000	12,846,000	19,500,000
Liquefiers	1,200	*920	*840	4,100	13,250

* Spores determined by heating to 65° C.

Age in days.	49.	57.	62.	68.	79.
Total number ..	3,730,000	3,285 000	60,300	67,460	24,500
Liquefiers	9,500	2,000	2,000	400	0

At the end of 62 days this cheese was pronounced ripened and of fine quality from the commercial standpoint.

These results are quite in accord with the determinations which we have made upon a considerable number of cheddar cheeses. During the early period of its life history when the cheese is rapidly passing through the ripening changes the flora consists very largely of lactic-acid organisms with a small proportion of liquefying bacteria.

EFFECT OF ACID UPON THE DIGESTIVE ACTION OF THE RENNET.

It has been known for many years that the use of larger quantities of rennet would quicken the rate of ripening in cheese and cheese-makers use this knowledge in hastening the ripening

of their product. However it was not until 1900[10] that experimental proof was brought forth to show that this quickening of the ripening process was due to the digestive action of a peptic enzyme in the rennet.

The part taken by the rennet enzyme in the ripening of cheese has been discussed at length in Bulletin No. 233 of this Station and the reader is referred to that bulletin for a detailed treatment of the subject. In the present connection it will be sufficient to point out that under normal conditions the change of sugar into acid is necessary in order that the peptic enzyme of the rennet may play its important part in the breaking down of the cheese casein. As illustrative of this point there is given below a summary of the chemical changes observed in two of a series of cheeses made for the purpose of studying this relation.

In order to measure the digestive action of the rennet it was necessary to remove the other factors which might assist in the breaking down of the casein. It has been shown in Bulletin No. 233 that a momentary heating to 85° C. will destroy the enzymes in the milk itself and the milk used in making these cheeses was heated above 95° C. for this purpose. In order to prevent bacterial action 2 to 3 per ct. of chloroform by volume was added to the milk shortly after the above heating.

The milk was made into cheese in the usual manner except that calcium chloride was added to the milk to assist the curdling action of the rennet. In cheese 6.17IV a total of .2 per ct. lactic acid was added in small diluted portions at intervals during the process of manufacture to simulate the formation of the same by bacteria under normal conditions. In 6.17V this acid was omitted.

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[10] Babcock, Russell & Vivian. Ann. Rept. Wis. Station, **17**:102. (1900.) Also *Cent. f. Bakt.*, II Abt., **6**:817. (1900.)

Jensen. *Landw. Jahrb. d. Schweiz.*, **14**:197. (1900). Also *Cent. f. Bakt.* II Abt. **6**:734. (1900.)

TABLE V.—EFFECT OF ACID COMPOUNDS UPON THE DIGESTIVE ACTION OF THE RENNET.

Age in months.	Percentage of nitrogen of total nitrogen in cheese.			
	6.17 IV (acid).		6.17 V (no acid).	
	Salt-soluble.	Water-soluble.	Salt-soluble.	Water-soluble.
	Per ct.	Per ct.	Per ct.	Per ct.
Initial.	26.62	5.40	2.90	3.67
3	28.52	11.66	3.12	5.78
6	19.06	18.90	3.03	8.81
9	19.94	17 17	2.47	5.99
12	11.97	18.50	3.46	6.41

From the above results it is clearly seen that in the presence of the salt-soluble compound the rennet enzyme was able to change considerable quantities of nitrogen into a water-soluble form while under similar conditions except for the action of the acid the rennet enzyme did very little work. From this we conclude that the activity of the lactic-acid bacteria in changing sugar into acid is a necessary preliminary to the digestive action of the rennet in cheese under normal conditions.

CONCLUSION.

In the preceding pages the attempt has been made to follow the process of cheese-making and the first steps of cheese-ripening and to trace in outline the part played by the acid-forming bacteria. It has been shown that all of the observed changes up to the point where the digestion by the rennet leaves off are either the direct result of the action of these bacteria or are largely influenced by bacterial action.

A discussion of the early stages of cheese-ripening would be incomplete unless consideration was given to the part played by the enzymes of the milk itself. However, the effect of these enzymes is not confined to the first stages of the ripening, and as the subject will be later treated in a separate bulletin it will not be further discussed at this time.

Under the conditions which exist in normal cheddar cheese the action of the rennet enzymes probably extends but little beyond

the formation of peptones, while a ripened cheese is characterized by the presence of large quantities of the simpler nitrogenous compounds. Since the flavors, which lend greatest value to cheese, are probably associated with the formation of these simpler compounds, this unexplained portion of cheese-ripening is of the greatest practical interest and the influence of bacteria upon this formation as well as the part taken in the same by the enzymes of the milk are at present the subject of investigation.

AT WHAT TEMPERATURE SHOULD PEAS BE PROCESSED?*

H. A. HARDING AND J. F. NICHOLSON.

Our attention has been called to the losses which occur due to the swelling of canned peas. The cause of this trouble has been found and a temperature at which the trouble can be controlled has been determined. Before making final recommendations it is desired to test a number of temperatures upon cans of fresh peas to find the effect upon their commercial value. This circular is a report of work done and is intended for those engaged in the canning industry with the hope that it may be of some use to them during the present season. We wish to acknowledge our indebtedness to the canners for their suggestions and coöperation and especially request information upon the effect of various temperatures upon the commercial quality.

Cause of the swelling.—The swelling is due to gas produced by bacteria growing within the cans. It is quite possible that different species of bacteria might cause this swelling but thus far we have found but a single form that seems to be responsible for this trouble on a commercial scale. The spore-forming bacillus is hard to kill because it forms unusually resistant spores. These spores are so resistant that any treatment which will destroy them will probably suffice for any other forms which may be present.

Source of the bacilli.—The source of the gas-forming baccilli, whether from the factory or the pea vines, has not been determined. They do not seem to be always present in either, since during some

*A reprint of Circular No. 3, new series.

seasons peas are successfully handled at a temperature below that necessary to destroy these germs.

How to detect quickly.—The bacillus grows rapidly at about blood heat. If alive in the processed cans the fact will be shown in a few days by holding samples of each day's pack at this temperature.

How controlled.—The simplest method of control lies in raising the temperature or extending the time of processing. The following data give the results of processing two-pound cans of peas at different temperatures and for different lengths of time. In all cases cans which have been previously sterilized were inoculated with large numbers of the spores of the gas-forming bacillus shortly before being heated.

TWO POUND CANS OF PEAS HEATED TO 230° F. AT LABORATORY.

Time in minutes	20	25	30	35	40
No. cans heated	6	6	6	6	3
No. cans swelled	5	6	1	0	0
Percentage swelled	83	100	16	0	0

The number of cans used in this experiment was too small to give more than a general idea of the effect of processing at 230° F. for various lengths of time. The temperature of 230° F. for 30 minutes had been tried on a large scale at a factory where the gas-forming bacillus was present. The loss was approximately 90 per cent.

TWO POUND CANS OF PEAS HEATED TO 236° F. AT LABORATORY.

Time in minutes	15	20	25	30	35	40	45
No. cans heated	10	10	34	34	76	48	24
No. cans swelled	10	6	8	3	7	8	2
Percentage swelled	100	60	23	9	9	16	8

This table is the combination of the results of four separate trials. The irregularities in the results obtained by processing at 236° F.

would indicate that this temperature marked about the limit of resistance on the part of the germ. Variations in the age of the peas, in the density of the same in the cans, and other like factors would then show their maximum influence on the results of the heating. It should also be remembered that in the experimental cans the amount of infection was much greater than would be expected in nature, and the chance of an unusually resistant spore surviving was correspondingly increased.

In the same factory where the heating at 230° F. for 30 minutes had failed so completely a heating at 238° F. for 35 minutes gave good results, the loss being no greater than that ordinarily attributed to leaks in the cans.

TWO POUND CANS OF PEAS HEATED TO 240° F. AT LABORATORY.

Time in minutes	15	20	25	30
No. cans heated	12	12	12	36
No. cans swelled	0	0	0	0
Percentage swelled	0	0	0	0

The results at 240° F. are very uniform. This uniformity is more striking from the fact that cans were tested at this temperature on the same days, inoculted with portions of the same culture as that used in three of the tests at 236° F. where the results were so irregular. It would seem that 240° F. quickly destroys the germs but the number of cans is so small that it would not be safe, on the basis of these figures, to risk processing at this temperature for less than 20–25 minutes.

The effect upon the commercial quality of a short exposure to 240° F. has not been accurately determined and there seems to be a difference of opinion upon this point among canners. It is probable that at least within some grades of peas this is very close to the limit of the heating compatible with a first-class product.

Conclusions.—In processing two-pound cans of peas, 230° F. for 30 minutes is not sufficient when the gas-forming bacillus is present. It appears that 236° F. for 30 minutes is about the minimum exposure which should be used and 238° F. for 35 minutes has been found successful in practice. The use of 240° F. for 20–25 minutes will probably sterilize the peas but its effect upon the commercial quality has not been satisfactorily settled.

REPORT

OF THE

Department of Botany.

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REPORT OF THE DEPARTMENT OF BOTANY.

COMBATING THE BLACK ROT OF CABBAGE BY THE REMOVAL OF AFFECTED LEAVES.*

F. C. STEWART AND H. A. HARDING.

SUMMARY.

Black rot is destructive to cabbage and cauliflower in New York. It is a bacterial disease the chief diagnostic character of which is the appearance of black streaks in the woody portion of the stem and in the leaf-stalks.

As a preventive of the disease, other investigators have recommended the leaf-pulling treatment which consists in removing all affected leaves at frequent intervals. During the past four years the writers have made practical field tests of this treatment and found it to be worthless.

Each season the experiment field was one acre in extent, one-half being treated and the other half used as a check. During the first three seasons there was not enough black rot to give the treatment a fair trial; but in 1902 there was a moderate attack of the disease. All diseased leaves were carefully removed once a week from July 22 to September 16. The treatment not only failed to check the disease but reduced the yield by 5,285 lbs. on one-half acre, or at the rate of 5¼ tons per acre.

*A reprint of Bulletin No. 232.

The treatment fails for the following reasons: (1) The removal of so many leaves checks the growth of the plants. In a supplementary experiment made in 1900 the removal of 10 leaves (one or two each week) from each plant reduced the yield by 42.8 per ct., or at the rate of three tons per acre (page 106); (2) Infection occurs through the roots as well as by the way of the leaves; (3) Infection may occur at the base of the leaf close to the stem and get into the stem unobserved; (4) The germs of the disease are so widely and so abundantly distributed that it is useless to try to stamp out the disease by the removal of diseased material.

No successful method of combating the disease is known. Further experiments on treatment are in progress; also, investigations on the mode of infection and dissemination, as it is believed that these fundamental problems must be solved before much progress can be made toward the control of the disease.

INTRODUCTION.

The principal object of this bulletin is to give an account of some recent field experiments on the treatment of the black rot[1] of cabbage by the prompt removal of affected leaves. This line of treatment, having been wholly unsuccessful, will hereafter be abandoned; but experiments on the treatment of the disease, on both cabbage and cauliflower, will be continued along other lines. There are in progress also, supplementary investigations on the disease itself and on a soft rot[2] frequently associated with it. Inasmuch as other and more exhaustive publications on black rot are contemplated by the writers only a brief account of the disease will be given at this time. Those wishing a more complete account should consult Wis. Agr. Exp. Sta. Bul. 65, A Bacterial Rot of Cabbage and Allied Plants; and U. S. Dep't of Agr. Farmers' Bul. 68, The Black Rot of the Cabbage.

THE DISEASE.

ECONOMIC IMPORTANCE IN NEW YORK.

An epidemic of black rot on cabbage and cauliflower occurred on Long Island in 1895–6 and in 1898 the cabbage raising sections in the central and western portions of the State were swept by this trouble. In some cases entire fields were totally destroyed by this disease and the loss throughout the State amounted to many thousands of dollars. Since 1898, while the damage has been less universal, there have been each year isolated fields where the loss was considerable. The financial loss upon cabbage occurs principally upon the later varieties, the Danish being especially subject to attack.

PREVIOUS INVESTIGATIONS.

This disease of cabbage and cauliflower was first reported by Garman[2a] in 1890, was studied by one of us on Long Island in

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[1] *Pseudomonas campestris* (Pam.) Smith.

[2] A preliminary report of the investigations on soft rot was published in *Science*, N. S., **16**: 314–315. Aug. 22, 1902.

[2a] Garman, H. A Bacterial Disease of Cabbage. Ky. Exp. Stat. Rep. 1890: 43.

1895, was described by H. L. Russell at the Springfield meeting of the American Association for the Advancement of Science in August, 1895, and later was studied extensively at the Wisconsin Agricultural Experiment Station and at the Department of Agriculture at Washington. Extended accounts of the disease and its cause were published by E. F. Smith in the *Centralblatt für Bakteriologie*, II Abteilung, Vol. 3, and in Farmer's Bulletin 68 of the Department of Agriculture, as well as by Russell & Harding in Bulletin 65 of the Wisconsin Agricultural Experiment Station.

APPEARANCE OF AFFECTED PLANTS.

The first evidence of disease usually appears in the latter part of July when the more advanced plants of late cabbage are beginning to form heads. The first symptoms of an outbreak are easily recognized on a hot, dry afternoon when a number of the plants will appear wilted and lighter green in color. A cross section of the stem of these plants near the ground shows that many of the water-carrying fibro-vascular bundles are black; and on splitting the stem these black lines can be followed down to the withered extremity of the tap root. A diseased condition of any considerable number of these bundles curtails the water supply and when atmospheric conditions are favorable for rapid evaporation from the leaves the latter quickly wilt.

The upward movement of the water carries the disease along the bundles out into the leaves. As soon as the bundles supplying any considerable portion of a leaf become diseased that part of the leaf dies for lack of water. The blade of the leaf becomes light brown and has a texture like parchment. It is semi-transparent and when closely examined the network of fine veinlets which have been turned black by the disease stands out sharply in the brown background.

Early in August the disease commonly manifests itself in another form. Brown spots appear at the margin of many of the leaves (see Plate I) especially of those which come in contact with the soil. These brown areas spread toward the center of the leaf and a close examination shows the fine veins to be blackened. In from one to three weeks, depending on circumstances, the

PLATE I.—CABBAGE LEAF AFFECTED WITH BLACK ROT, WATER PORE INFECTIONS.

disease usually reaches the stem of the plant. The progress of the disease from this point is identical with that brought about by infection through the root.

In either form of infection the most reliable diagnostic character of the disease is the blackening of the fibro-vascular bundles. These bundles may be readily inspected by cutting across the leaf petiole or the stem.

The failure to supply sufficient water checks growth and often results in the death of the plant. The fibro-vascular bundles do not branch freely in the stem and in cases where the disease gains a foothold only on one side of the plant the growth on that side is retarded so as to produce a marked curvature. The lower leaves turn brown and drop off, but when the plant succeeds in forming a head the upper leaves are held in place and often turn black and decay thus destroying the commercial value of the head.

The extreme variation in the activity of this disease in different years depends largely upon weather conditions. A combination of abundant moisture with high temperature during August and September is favorable for an epidemic.

CAUSED BY BACTERIA.

The blackening of the fibro-vascular bundles and the accompanying decrease in the water flow is due to the growth in the tissue of a bacterium known as *Pseudomonas campestris* (Pam.) Smith. This is the fact in connection with the disease which has been most carefully established. The tissue of healthy plants is free from germ life, but large numbers of *Pseudomonas campestris* are constantly found in these blackened bundles. Germs obtained in this way from diseased plants at such widely separated points as Wisconsin, New York and Switzerland were carefully studied and found to be of this species.[3] When pure cultures of *P. campestris* were introduced into the stem of healthy plants under circumstances which prevented the entrance of other forms the characteristic phenomena of the disease were reproduced.

[3] Harding, H. A., Die schwarze Fäulnis des Kohls und verwandter Pflanzen, eine in Europa weit verbreitete bakterielle Pflanzenkrankheit. *Centralbl. f. Bakt.*, II Abt., **6**: 305. 1900.

From blackened bundles resulting from these artificial inoculations and at considerable distances from the point of infection, in tissue which had been formed subsequent to the inoculation, pure cultures of *P. campestris* were obtained. This completes the proof considered necessary to establish the causal relation of an organism to a given disease.

MODE OF INFECTION.

There are at least three avenues through which these germs may gain access to the plants:

(1) At the time of transplanting into the field some of the roots are broken, exposing the ends of the fibro-vascular bundles to the attack of *P. campestris* in the soil. The plants which wilt badly within a few weeks often have many black fibro-vascular bundles in the stem when there is no evidence of the disease in the leaves. (See page 103.) This mode of infection seems to be most active during the early life of the plants.

(2) Insects, by eating the leaf tissue, expose the cut ends of the fibro-vascular bundles and either infect these directly by their jaws or leave the surfaces in condition to be infected from other sources. This avenue of infection appears to be more important with cauliflower than with cabbage, but in either case is of secondary importance.

(3) Under favorable atmospheric conditions the water pores at the margin of the leaves exude liquid. Any germs which find their way into these drops after swimming back through the opening of the water pore find themselves at the termination of a fibro-vascular bundle. A great majority of the infections occurring during the month of August can be traced to this source. Sometimes as many as a hundred cases of this form of infection may be seen on a single large plant.

MODE OF DISSEMINATION.

The natural habitat of *P. campestris* and the ways in which it is distributed from plant to plant have not been satisfactorily worked out. Observations made in connection with root infection makes it probable that *P. campestris* is able to live in the

soil in competition with the other forms found there. However, several attempts to isolate this organism from soil supposed to be infected have failed. On account of the large number of other forms present in soil a small number of *P. campestris* would be easily overlooked.

The first leaf infections take place in the outer leaves, which often come in contact with the soil. Later, infection occurs on the more central leaves which could hardly have been directly infected in this way. In the latter case the germs must have been carried to the water pores either by insects or air currents. In either case the germs would have been exposed to a considerable amount of dessication, something which they seem to be little fitted to withstand.

So far as is definitely known the transfer of the disease from one field to another is connected with the transfer of portions of diseased plants. The wind carries parts of diseased leaves for considerable distances. Along water courses in times of freshets the water deposits both soil and plant remains. By feeding to animals or otherwise disposing of rubbish, parts of diseased plants are often carried out upon new fields.

The disease sometimes appears in fields where none of the cabbage family has been cultivated for many years and where no known mode of infection is active.

EXPERIMENTS ON PREVENTION BY THE REMOVAL OF AFFECTED LEAVES.

WHY UNDERTAKEN.

Black rot being so destructive in New York in the season of 1898, there was an urgent demand from farmers for information concerning methods of combating it; and it became imperative that the Station should undertake some experiments on the treatment of the disease.

Both Russell[4] and Smith[5] had suggested the removal of affected leaves as being a promising line of treatment. They made some

[4] Russell, H. L. A Bacterial Rot of Cabbage and Allied Plants. Wis. Agr. Exp. Sta. Bul. 65 : 38, 39.

[5] Smith, Erwin F. The Black Rot of the Cabbage. U. S. Dep't of Agr. Farmers' Bul. 68 : 14.

experiments, the results of which indicated that the disease might be controlled in this way. Russell[6] says:

On the horticultural grounds at the University, cauliflower was planted on soil that had borne a similar crop the previous year, and one which was somewhat affected with the rot. This field was allowed to develop in the usual manner until September of this year. By the first of the month, the patch began to show evidence that the disease was pretty generally distributed. At this date it was divided into four sections and from alternate sections the attempt was made to stop the disease by removing the affected leaves. The other two sections were left under natural conditions and no attempt was made to check the spread of the malady. The result of this experiment was that the disease was held completely in check. Several plants became infected subsequent to the removal of the diseased leaves, but by removing all of these later the further progress of the disease was brought to a standstill.

The continued spread of the disease in the uncontrolled sections showed that the disease organism was being thoroughly distributed and therefore the failure to spread was not due to absence of disease virus.

Another experiment was also carried out on a larger scale under commercial conditions. A field of about three acres of cabbage near Berryville, Wis., was noted that had been planted on new ground that had never had cabbage on it before. When first observed on September 1st, of this year, the cabbage rot was just beginning to make its appearance. In some cases where the plants were small the disease had established itself in the stem, but in the majority of cases only individual leaves were affected. At our suggestion, the owner decided to remove all diseased leaves and badly affected plants in order to see whether the progress of the trouble might not be retarded. The result of this was that the repressive measures used kept the disease well in check. The patch was only fifteen rods distant from another field that was very severely affected, and of course the seeds of the disease were continually being distributed by means of the wind. The disease made but slow headway as the season was unusually dry. Yet under the same atmospheric and soil conditions, in another large patch in which no repressive measures were attempted the disease developed severely.

Smith[7] says:

This method was tried by the writer in August, 1897, on about four hundred plants, with very satisfactory results, four-fifths of the heads being free from the disease when harvested in November. The one-fifth may have been diseased in the stem at the time the leaves were broken off, or may have subsequently contracted the disease through other leaves.

These experiments were all faulty in that no account was taken of the all-important factor of yield. In Smith's experiment no check is mentioned and Russell's cabbage experiment was also without a proper check.

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[6] Russell, H. L. Loc. cit.

[7] Smith, Erwin F. Loc. cit.

However, the results appeared encouraging and from theoretical considerations it seemed reasonable to expect that the leaf-pulling treatment might be successful. Moreover, it was, at that time, the only line of treatment which had been suggested.

Accordingly, the writers set out to test it thoroughly and determine definitely whether it is a preventive of the disease, and also whether it is a profitable operation under commercial conditions.

METHOD OF TREATMENT DESCRIBED.

In general, the method of treatment is as follows:

The plants are carefully watched for the first appearance of the disease, which usually occurs about August 1. Thereafter, the field is gone over, row by row, once a week, and every leaf showing signs of the disease is broken off and carried out of the field. Whenever there is found a plant in which the disease has already gotten into the stem, as shown by the presence of black streaks in the basal portion of the leaf stalks, such plant is promptly removed from the field. It has been the practice of the writers to carry a large market basket into which the diseased leaves are placed as fast as gathered. When the basket is filled it is carried to the margin of the field and emptied.

It may be stated here that in the experiments described in this bulletin the work of removing the diseased leaves was not entrusted to laborers. Most of it was done by the writers themselves and the remainder by Messrs. F. M. Rolfs and H. J. Eustace, assistants in the Botanical Department, and L. A. Rogers and J. F. Nicholson, assistants in the Bacteriological Department. The writers wish to thank these gentlemen for their efficient assistance.

THEORY OF THE TREATMENT.

In many cases the disease starts at the margin of the leaf (see Plate I); sometimes, also, in leaf wounds made by insects, and then passes downward along the fibro-vascular bundles (veins) into the stem of the plant.

As a rule, several days are required for the disease to reach the stem. Once the disease is within the stem it is beyond con-

trol and the plant is likely to be ruined; but if the affected leaf were removed before the disease had reached the stem the plant would be saved. Moreover, the diseased leaves, if not removed, become a source of infection to neighboring plants, particularly when the affected plant dies and decays. Hence, the seeming importance of carrying all affected leaves and plants from the field.

Briefly stated, the treatment aims at two things: (1) To save plants already slightly affected; and (2) To prevent the spread of the disease by the removal of the causal organism.

EXPERIMENTS PRIOR TO 1902.

In 1899.—The field selected for the experiment was one on which the cabbage crop had been practically ruined by black rot the preceding season. It contained exactly one acre, was trapezoidal in shape and about twice as long as wide. It lay on river bottom land near Phelps, N. Y., on the farm of Mr. David White. The soil was a sandy loam well adapted to the growth of cabbage.

The plants were of the variety Danish Ball Head, set June 15, 33 inches apart each way. They were carefully watched in the seed bed and showed no signs of black rot at the time of transplanting.

The field was divided crosswise into two equal parts each containing one-half acre. On one half-acre all affected leaves were to be removed once a week throughout the season, while the other half acre was to serve as a check.

On the half-acre to be treated one affected leaf was found July 20 and by July 28 there were about 20 leaves with one or more small brown marginal areas of uncertain origin; but the first real outbreak of black rot was noted August 4, on which date the first treatment was made. For each treatment a record was kept of the time consumed, the number of leaves removed, the number of points of infection and the number of plants removed because of disease in the stem. These data are shown in the following table:

TABLE I.—DATA OF THE CABBAGE ROT EXPERIMENT IN 1899.

Date of treatment.	Time consumed.	Diseased leaves removed.	Points of infection.	Whole plants removed.
	Hrs.	*No.*	*No.*	*No.*
August 4	1½	181	408	0
" 10	1½	195	299	0
" 17	1½	59	72	2
" 25	1½	47	75	0
" 31	1½	52	68	7
September 9	1¾	46	54	17
" 15	1	36	46	7
" 22	1	18	25	7
Totals	11¼	634	1,047	40

In addition to the 634 affected leaves there were removed a considerable number of leaves showing brown marginal areas which, upon close examination, were found to be due to causes other than black rot. In four seasons' experience the writers have found that in order to be on the safe side it is always necessary to remove a good many leaves which may not be really affected with black rot but which present symptoms so similar that a close examination is required for a correct diagnosis.

The principal part of the crop was harvested and marketed on November 4 and 6; but some immature heads were allowed to stand until November 21. For each half acre a record was kept of the number of marketable heads and their weight; also of the number of heads showing well defined symptoms of black rot, those showing traces of black rot and those with soft rot in the stem. These data are given in the following table:

TABLE II.—RESULTS OF CABBAGE ROT EXPERIMENT IN 1899.

Quality.	Treated half-acre.		Check half-acre.	
	Heads.	Weight.	Heads.	Weight.
	No.	*Lbs.*	*No.*	*Lbs*
Marketable (1st cutting)	2,200	13,710	1,835	9,750
" (2d cutting)	200	200	503	500
" (total)	2,400	13,910	2,338	10,250
Showing black rot, definitely	11		11	
" " " traces	6		6	
" soft rot in stem	5		6	

The treated half-acre yielded 2,660 lbs. more than the check. This is at the rate of 5,320 lbs. or over 2½ tons per acre. However, this difference can not have been the result of the treatment. Close observation led to the conclusion that neither the check nor the treated half-acre was materially injured by the disease. The plants on the check, which was next the river, were considerably injured by muskrats and it is believed that the damage was sufficient to account for the difference in yield.

Because of the small amount of disease this experiment teaches very little as to the value of the treatment; but it does show that it is possible to secure a fair crop of cabbage (12 tons per acre) on land on which the disease has been previously destructive.

In 1900.—The field used for the experiment in 1900 was the same as that used in 1899. The variety of cabbage, Danish Ball Head, was also the same. Previous to planting, the seed was soaked for 15 minutes in a 1-1000 corrosive sublimate solution.[8] The seedlings were inspected June 19 and seemed to be wholly free from black rot. They were transplanted July 3 and 4. As in 1899, the field was divided crosswise into two equal parts—one part to be treated and the other part to be used for a check.

The first treatment was made on August 9 and repeated once a week thereafter until September 19. In all, seven treatments were made. At each treatment all leaves showing any indication of the disease whatever were removed and placed in a pile at the margin of the field. Afterward, they were counted and carefully examined for evidences of black rot. A record was kept of the number of leaves showing definite signs of black rot; also of the number of whole plants which it was necessary to remove because of the disease having gained access to the stem. All these data are given in the following table:

[8] The seed was treated with corrosive sublimate as a precaution against possible infection by germs on the seed. In experiments made by the writers cabbage seed soaked for one hour in a 1-1000 solution of corrosive sublimate and afterward rinsed with distilled water has germinated quite as well as untreated seed. It is safe to say that a 15-minute treatment of this kind will result in no injury to the seed.

TABLE III.—DATA OF THE CABBAGE ROT EXPERIMENT IN 1900.

Date of treatment.	Leaves removed.			Whole plants removed.
	Total.	Affected with black rot.	Not affected with black rot.	
	No.	*No.*	*No.*	*No.*
August 9	150	71	79	6
" 15	165	124	41	4
" 23	512	206	306	10
" 30	205	87	118	3
September 5	454	150	304	11
" 12	747	143	604	11
" 19	243	143	100	5
Totals	2,476	924	1.552	50

The crop was harvested November 12. A record was kept of the number of marketable heads and their weight; also, of the number of heads too small for market, but no account was taken of plants which failed to head. All heads, both marketable and small, were examined for evidences of black rot. These data are fully shown in the following table:

TABLE IV.—RESULTS OF CABBAGE ROT EXPERIMENT IN 1900.

Quality.	Treated half-acre.		Check half-acre.	
	Heads.	Weight.	Heads.	Weight.
	No.	*Lbs.*	*No.*	*Lbs.*
Marketable	1,452	6,680	1,225	4,500
Small	1,069		1,273	
Affected with black rot	60		142	

As in 1899, the greater yield of the treated half-acre was not the result of the treatment. Again, the check was the most injured by the muskrats. Another thing which reduced the yield on the check was the supplementary leaf-pulling experiment conducted there. (See page 105.) On account of this experiment the number of marketable heads was reduced by 207 and the yield by 1151 lbs., which should be added to the figures given in the above table. Thus corrected, the yield of the check would be 1432 marketable heads having a weight of 5651 lbs.

Black rot, although somewhat more abundant than in 1899, was not sufficiently destructive to affect the yield. Consequently, the experiment was again a failure so far as throwing light on the value of the treatment is concerned. This season the plants were considerably injured by drought.

In 1901.—This year the location of the experiment field was changed. An acre was laid off in the center of a field of Danish Ball Head cabbage a few rods from the former field and on soil of the same character but a little higher and drier. The plants had been set June 21. The field was divided into two equal parts, one part being treated and the other a check. The treatments were made weekly commencing August 9 and closing September 21.

The plants grew vigorously from the start. Although black rot made its appearance at the usual time, the first week in August, it did no damage worth mentioning and for the third time the experiment failed of results because of a lack of the disease. During the whole season there appeared upon the treated half acre only 150 affected leaves and 12 plants affected in the stem.

Owing to trouble with a produce dealer to whom the crop was sold the Station was prevented from harvesting the cabbages until they had been ruined by freezing and consequently no record of the yield was obtained; but it was estimated to be from 13 to 16 tons.

EXPERIMENT IN 1902.

Having, for three consecutive seasons, failed to secure a sufficient amount of the disease, it was decided to adopt a new method of selecting a field for the experiment. Commencing about July 10, cabbage fields in the vicinity of Geneva and Phelps were carefully watched for the appearance of black rot, the plan being to locate a field in which there promised to be an epidemic of the disease and then arrange to make the experiment there.

A suitable field was found, July 16, on a farm near Phelps, leased by Mr. Charles D. White. Many leaves were already showing unmistakable signs of infection, and it seemed likely that there would be a serious outbreak of black rot.

The plants had been set, 33 inches apart each way, about June 25. On one side of the field there was laid off an exact acre, twice as long as wide, and containing 54 rows of 108 plants each. The acre was so located as to cover 27 rows of each of two varieties, Danish Ball Head and Henderson's Succession. It was divided, crosswise, into two equal parts—one part to be treated and the other used as a check. By this arrangement each half acre contained 27 rows (54 plants each) of Danish Ball Head and 27 rows of Henderson's Succession. (See the accompanying diagram.)

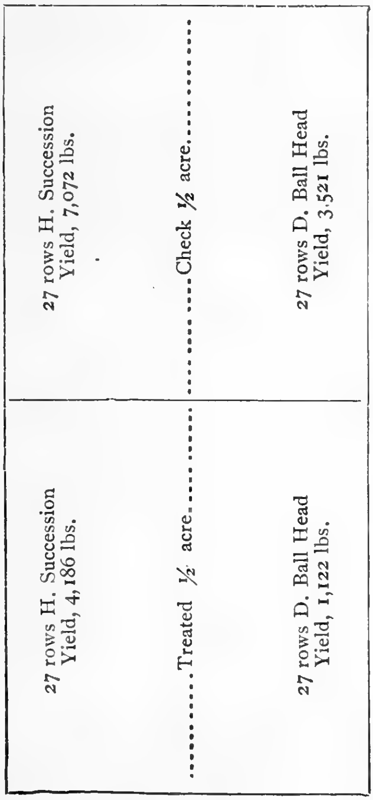

DIAGRAM I.—SHOWING SHAPE, ARRANGEMENT AND YIELD OF PLATS IN THE CABBAGE ROT EXPERIMENT AT PHELPS IN 1902.

From the plants on the treated half-acre all diseased leaves were removed once a week on the following dates: July 22 and 29; August 5, 12, 19 and 26; September 2, 9 and 16. The total amount of time required to make these nine treatments on one half-acre was 46½ hours for one man.

At the time of the first treatment, July 22, it was estimated that 33 per ct. of all the plants were showing more or less leaf infection. From this time until well into September the disease continued active. At each treatment there were multitudes of diseased leaves to be found notwithstanding every diseased leaf had been removed one week previous. In spite of all that could be done large numbers of new infections continued to appear. For a time every plant found to be affected in the stem was removed as in previous experiments; but this was soon abandoned as it was plain that it would result in a serious depletion of the treated plat. Although the disease was so abundant that on the check plat scarcely a single plant wholly free from it could be found by September 2, only a few plants were completely ruined by it, and the attack is to be regarded as only a moderate one.[9] This view is supported by the yield on the check plat which was at the rate of over ten tons per acre.

The 27 rows of Henderson's Succession were harvested October 13 and the 27 rows of Danish Ball Head, November 8. The results are shown in the following table:

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[9] Black rot is not so certainly fatal as one might infer from the literature of the subject. A good yield of cabbage may often be obtained from fields in which almost every plant shows more or less infection. This may be true even when the infection occurs early in the season. Plants infected within a month after transplanting may live to produce marketable heads of good size. Even plants in which the disease has gained access to the main stem often produce marketable heads and the removal of such plants causes unnecessary loss. The rapidity with which the disease progresses within the plant is greatly influenced by weather conditions and the condition of the plant.

Black rot appeared abundantly in many fields in the vicinity of Geneva about August 1, 1899, but drought during the next two months decreased the succulence of the plants and seemed to check the progress of the disease.

During the season of 1902 there was an abundance of moisture, but the temperature was unusually low, and while nearly every plant in our experiment field contracted the disease few were destroyed.

TABLE V.—RESULTS OF CABBAGE ROT EXPERIMENT IN 1902.

Variety.	Treated half-acre, one half to each variety.		Check half-acre, one-half to each variety.	
	Heads.	Weight.	Heads.	Weight.
	No.	*Lbs.*	*No.*	*Lbs.*
Henderson's Succession	894	4,186	1,175	7,072
Danish Ball Head	302	1,122	761	3,521
Total	1,196	5,308	1,936	10,593

The treatment resulted in a loss of 5285 lbs., which is at the rate of 5 1-4 tons per acre.

Although the affected heads were not counted there were apparently about the same number on the treated portion as on the check. On both plats a few heads were affected with soft rot externally and a few with soft rot in the stem.

The treatment was even more than a complete failure. It not only failed to prevent the disease, but actually reduced the yield by 5¼ tons per acre. This fact, taken in connection with the expense of the treatment, which was $11.62 per acre (counting labor at 12½ cents per hour), makes the treatment highly unprofitable. The worthlessness of the leaf-pulling treatment is so thoroughly demonstrated by this experiment that further experimentation along this line has been abandoned.

WHY THE LEAF-PULLING TREATMENT FAILS.

Removal of leaves checks the formation of heads.—Even if black rot could be controlled by the removal of diseased leaves the treatment could not be made a profitable operation for the reason that it reduces the yield. The removal of affected leaves checks the growth of the heads. In order that the treatment may be effective it is necessary to remove all affected leaves, even those showing only traces of infection and also many others not really affected. (See page 95 and Table III.) The loss of so many leaves is a great drain upon the plants. If these leaves were not removed they would continue to perform their function for a considerable length of time in spite of the fact that they were

diseased. Very frequently, it is necessary to remove large leaves having an area of 60 to 80 square inches because of a single diseased spot, perhaps an inch square, on the margin.[10] It might be two or three weeks or even more before such a spot would enlarge sufficiently to seriously impair the usefulness of the leaf.

In the experiment made in 1902 (page 98) the plants on the treated half-acre had a trimmed-up appearance due to the removal of many diseased leaves. This was very noticeable. Toward the close of the season many plants were entirely destitute of stem leaves. As a consequence, the heads were small and it was plain that the removal of the leaves had been decidedly injurious. This opinion is fully sustained by the fact that the yield of the treated half-acre was at the rate of $5\frac{1}{4}$ tons per acre less than that of the check. (See Table V, page 101.)

Infection occurs through the roots as well as on the leaves.—Russell[11] and Smith[12] demonstrated beyond doubt that infection very frequently occurs through the water pores at the margins of the leaves and, sometimes, also in leaf wounds made by insects. The leaf-pulling treatment is based on the assumption that these are the chief modes of infection. In fact no other mode of infection has been seriously considered, although there is a popular opinion among farmers that the disease is often communicated through the seed.

Field observations made in 1901 led the writers to suspect that infection may also occur through the roots. This suspicion was greatly strengthened by observations made on the experiment field at Phelps in 1902. Within a month from the time the plants were transplanted many of them were showing signs of infection in the stem without any leaf symptoms whatever. It was ob-

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[10] The question may be asked, Why not break off only as much of the leaf as may be necessary to remove the diseased area? This is impractical for two reasons: (1) It consumes too much time; and (2) The writers have observed that in a large percentage of the cases in which this has been done the broken leaf-margin has promptly become reinfected, possibly from germs on the hand of the operator.

[11] Russell, H. L. Loc. cit. pp. 27–30.

[12] Smith, Erwin F. *Pseudomonas campestris* (Pammel). The Cause of a Brown Rot in Cruciferous Plants. *Centralbl. f. Bakt., Parasitenk.* etc., II Abt., **3**: 409–413.

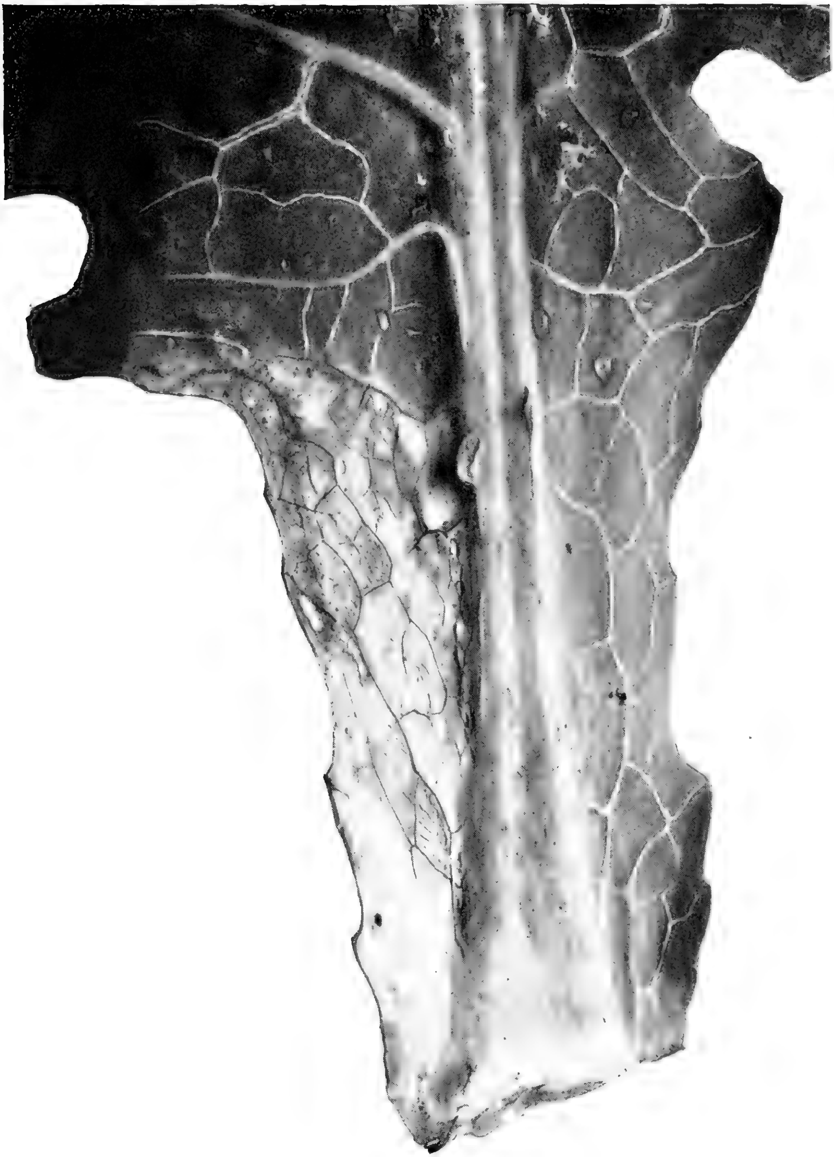

Plate II.—Cabbage Leaf Affected with Black Rot on the Leaf Stalk Close to the Stem.

served that the plants were very uneven in size.[13] Some grew vigorously while others, scattered here and there through the field, were small and some of them were wilting in spite of the fact that the ground was saturated with water. An examination of the wilted plants showed the lower portion of the tap-root to be dead and the fibro-vascular bundles in the stem blackened as in black rot. If this bundle blackening was really due to *Pseudomonas campestris* (which was proven in one instance) the plants must have been infected through the roots. This point will be further investigated during the coming season.

If root infection is as common as it appears to be it is a very important factor in the treatment of the disease. Root-infected plants can not be cured and no method of treatment which deals only with the parts of the plants above ground, such as leaf-pulling or spraying, can give any protection against root infection.

Infection occurs at base of leaves close to the stem.—One object in removing affected leaves is to prevent the disease from passing down the fibro-vascular bundles into the stem where it is beyond control. When infection occurs on the margin of the leaf at some distance from the stem this is easily accomplished; but the writers have found that infection often occurs on the basal portion of the leaf within one or two inches of the stem and gets into the stem before it is observed. (See Plate II.)

Many cabbage leaves have no well-defined petiole. Toward the base the stout midrib is bordered on either side by a narrow strip (one-fourth to one inch wide) of thin leaf tissue. Infection is as likely to occur here as on any other portion of the leaf and is apt to be overlooked because the closely-overlapping leaves hide it. In a few days the disease has gained access to the stem and then its progress can not be checked. This is one of the difficulties in the way of the successful application of the leaf-pulling treatment.

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[13] In this connection it is interesting to note Russell's observation (Loc. cit. p. 39) that: "In some cases where the plants were small the disease had established itself in the stem, but in the majority of cases only individual leaves were affected." This was on September 1, when the disease was "just beginning to make its appearance." Probably, the small plants had been infected through the roots and their small size was the consequence of such infection.

The black rot germs are widely distributed.—As yet there is very little exact knowledge concerning the mode of dissemination of the black rot germs. Either the germs are now abundant in nearly all soils in the cabbage-raising sections of the State, or else they are disseminated with remarkable facility. Although the virulence of the disease varies greatly in different fields it is rare to find a field wholly exempt if the season is at all favorable for the disease. It is very often destructive in fields which have never before grown cabbage or other cultivated plants of the cabbage family.

Because of the wide distribution of the disease germs it is apparently useless to attempt to prevent the spread of the disease by the removal of diseased plants. At least, no success is to be expected until it is definitely known how the germs are disseminated.

EXPERIMENTS ON CAULIFLOWER.

During the past four seasons in which the cabbage experiments have been in progress at Phelps similar experiments have been carried on with cauliflower on Long Island; but these experiments have been barren of results because of a lack of the disease. During four consecutive seasons there was not enough black rot in the experiment fields to give the leaf-pulling treatment a fair trial. Nevertheless, it will be abandoned. Since it is a pronounced failure with cabbage it is altogether likely that it will not succeed with cauliflower for the same reasons.

On cauliflower, spraying with resin-bordeaux mixture[14] has also been tried during four seasons. Owing to a scarcity of the disease the results are inconclusive but sufficiently encouraging to warrant the continuation of the experiments.

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[14] For the preparation of resin-bordeaux mixture see Bulletin 188 of this Station, page 247, footnote.

AN EXPERIMENT TO DETERMINE HOW THE REMOVAL OF THE LOWER LEAVES AFFECTS THE YIELD OF CABBAGE PLANTS.

In the experiments on the treatment of black rot by the removal of diseased leaves it soon became evident to the writers that whenever there was a destructive outbreak of the disease it would be necessary to remove large numbers of leaves and this raised the question as to what would be the effect on the yield of the plants.

The leaves of plants are important organs. It is in the leaves that the inorganic food substances taken from the soil are worked over into organic compounds which can be used by the plant to make further growth. If the leaves are destroyed by disease, insects or other agency the growth of the plant is checked. This is a general law among leafy plants and there seems to be no good reason for believing the cabbage plant to be an exception to the rule. However, it is stoutly maintained by some farmers that the removal of a few of the lower leaves of cabbage plants is not only harmless but positively beneficial to the plants and tends to increase the size of the heads.

In order to get definite information on this point the following experiment was made at Phelps, N. Y., in 1900: On the untreated half of the acre used for black rot experiments in 1900 (see p. 96) sixty-four rows were designated for use in the experiment under consideration. There were 35 plants in each row. They were of the variety Danish Ball Head and transplanted July 3. From each plant in every alternate row the lower leaves were removed as follows:

August	9,	2	lower	leaves	removed	from	each	plant.
"	15,	2	"	"	"	"	"	"
"	30,	2	"	"	"	"	"	"
September	5,	1	"	"	"	"	"	"
"	12,	1	"	"	"	"	"	"
"	19,	1	"	"	"	"	"	"
"	27,	1	"	"	"	"	"	"

In the course of the season ten lower leaves were removed from each plant in the alternate rows. On November 12 the crop was harvested and the product of each row weighed separately. The results are shown in the following table:

TABLE VI.—YIELD OF CABBAGE AS AFFECTED BY REMOVAL OF LOWER LEAVES.

Leaves removed.			Check.		
Row.	No. marketable heads.	Weight in lbs.	Row.	No. marketable heads.	Weight in lbs.
1	10	33	2	16	56
3	12	31	4	23	102
5	17	56	6	26	103
7	13	42	8	20	81
9	20	62	10	27	110
11	18	53	12	23	87
13	21	65	14	24	103
15	21	67	16	23	100
17	13	41	18	23	91
19	15	57	20	21	80
21	12	34	22	19	77
23	14	46	24	21	79
25	14	45	26	20	77
27	16	58	28	27	104
29	16	56	30	24	97
31	14	47	32	21	89
33	17	56	34	18	80
35	20	66	36	22	95
37	10	31	38	24	98
39	18	58	40	25	104
41	14	44	42	26	96
43	19	68	44	25	95
45	13	42	46	22	82
47	16	48	48	20	78
49	20	60	50	21	77
51	17	58	52	24	98
53	17	55	54	23	86
55	13	40	56	18	61
57	10	28	58	17	60
59	17	61	60	15	49
61	8	23	62	20	72
63	4	10	64	8	25
Totals	479	1,541		686	2,692

In every instance, save one, the check row gave a larger number of marketable heads than did the adjacent row from which the leaves had been removed. The average weight of the heads was also greater. The difference in total yield was 1151 pounds, which is at the rate of three tons per acre. Expressed in terms of percentage the reduction in yield due to the removal of ten leaves from each plant was 42.8 per ct.

CONCERNING THE PREVENTION OF BLACK ROT.

No practical treatment for black rot has yet been discovered. It has been shown that the leaf-pulling treatment instead of being beneficial is positively harmful. Rotation of crops affords little if any protection against the disease. Placing the seed bed on soil which has never grown cabbage or related plants is a good practice, but it remains yet to be proven that it is of any real value as a preventive of black rot. Spraying with resin-bordeaux mixture is, perhaps, worthy of trial, but can not be relied upon to control the disease.

The virulence of the disease depends largely upon weather conditions, and it is unfortunate that the conditions most favorable to the growth of cabbage are also the most favorable to the disease. Rapidly growing plants are especially liable to be attacked.

It appears to the writers that before much progress can be made toward the control of the disease it will be necessary to determine more definitely how the germs spread from plant to plant and field to field; also, to what extent they live over winter in the soil, to what extent root infection occurs and whether the disease is transmitted through the seed.

TWO DECAYS OF STORED APPLES.*

H. J. EUSTACE

SUMMARY.

I. A rot of apples, very similar in gross characteristics to the "pink rot" caused by *Cephalothecium roseum*, is produced by a fungus of the genus *Hypochnus*.

Inoculation experiments prove the fungus to be parasitic on apple and pear. It is a wound parasite and cannot grow through sound epidermis.

Since only apples that were attacked by the scab were affected with the rot, the importance of spraying to prevent scab is again emphasized.

II. During the winter it was noticed that a peculiar core decay had developed in Baldwin apples. While the fruit appeared externally to be perfectly sound an area about the core was decayed.

The trouble could not be traced to fungi or bacteria. It did not seem to be influenced by the use or absence of fertilizers, nor to have any relation to the kind or soil, nor to imperfect ripening of the fruit. It may have been caused by overbearing, by the unusually wet season, or by the combination of these conditions.

Baldwin apples placed in cold storage (30° F.) in October were entirely free from even a trace of the decay in June.

*A reprint of Bulletin No. 235.

I. ANOTHER APPLE ROT FOLLOWING SCAB.

In Bulletin No. 227 of this Station[1] is described an apple rot following scab, to which the popular name " Pink Rot " has been given. Some weeks after that Bulletin had been sent to the printers, specimens of diseased Rhode Island Greening apples were received at the Station from a cold storage fruit house in Orleans county. The decayed areas on these fruits presented the same general appearance as the spots caused by *Cephalothecium roseum*, which affected so many of the Rhode Island Greening apples during the fall of 1902. However, a microscopic examination at once showed that the fungus associated with the decayed tissue of these apples was not *C. roseum*, but an entirely different one.

On account of this similarity to the decay caused by *C. roseum* and the fact that the fungus found associated with the decay of these apples seemed to be a very unusual one as a cause of fruit decay, especially of decay of fruits in cold storage houses, it was decided to make an investigation of it.

Affected apples when first taken out of storage, had the appearance shown in Plate III, Fig. 1. The fruit was marked with brown, sunken, decayed spots of various sizes up to an inch in diameter, circular in outline except where several had coalesced. The epidermis was often ruptured. After an affected apple had been left in a moist chamber for a few days an abundance of a dirty-white, cob-web-like mold would make its appearance on each decayed spot (Plate III, Fig. 2).

Examination of the center of these decayed spots showed in each case the presence of apple scab, *Fusicladium dendriticum*, making it appear that the fungus causing the rot had gained an entrance through the rupture made by the growth of the scab. It was noticeable that the rot did not develop under the large spots that seemed to have corked over, but upon the fresh and apparently young ones that were evidently formed late in the season.

In a comparison of the " Pink Rot " of apples caused by the

[1]Eustace, H. J. A Destructive Apple Rot Following Scab. N. Y Agr. Exp. Station Bul. 227. D. 1902.

fungus, *C. roseum*, and the decay caused by this new fungus there are some differences in gross appearance by which they can be distinguished. On fruit affected with *C. roseum* there is usually a conspicious white or pinkish growth of the fungus in the center of an affected spot; whereas this new fungus does not show at all conspiciously on the surface of a decayed spot until made to do so by artificial conditions. On fruit, *C. roseum* is a very shallow growing fungus, penetrating the tissue not much more than an eighth of an inch, while this new fungus grows much deeper and in its late stage extends to the core. The tissue decayed by *C. roseum* has a very characteristic and decidely bitter taste, but the tissue decayed by this other fungus is only slightly bitter.

The scantiness of the fruiting of the fungus both on affected apples and in pure cultures was very remarkable. On one of the diseased specimens first received there were found a few spores, but for some time afterward affected apples that were put in moist chambers refused to develop any spores of the fungus. In the greater number of the cultures made, using several different media, the fungus would not fruit, though there would develop an abundance of the mycelium. But late in April, several cultures made from diseased tissue from artificially inoculated apples produced spores in abundance, and about this time affected apples that had been placed in moist chambers also fruited.

A microscopic examination will at once show that the fungus associated with this decay is entirely different from *C. roseum*. As seen under a microscope the most prominent and striking thing about the fungus is the constant presence of clamp connections at each septum of the hyphae (Plate IV, Fig. 2). This character will be found very useful in identifying the fungus. As these clamp connections were known to occur chiefly on species of the Basidiomycetes—a class of fungi including the rusts, smuts, mushrooms and puff balls—to find them on a fungus causing a decay of apples was very unusual.

While we were engaged in making drawings of the fungus and attempting to classify it, specimens were shown to Mr. H. Hasselbring, who happened in the laboratory. Mr. Hasselbring expressed the opinion that it was a species of *Hypochnus*. Subse-

quent studies convinced us of the correctness of this determination, but whether the fungus is referable to any of the described species of *Hypochnus* we have been unable to decide.

There are over sixty species of *Hypochnus* described in Saccardo's *Sylloge Fungorum*, and all except three or four are recorded as saprophytes.

That a fungus belonging to a genus so generally regarded as saprophytic should be found as a parasite on fruit is remarkable. However, this was exactly the case when *C. roseum* became parasitic on apples in 1902. Previous to that time it had been regarded by mycologists as a harmless saprophyte.

The basidia of this fungus, *Hypochnus* sp., are loosely aggregated, and usually bear four sterigmata. The hymenium consists of loose floccose or arachnoid hyphae. The spores are uncolored and smooth, one-celled and usually obovate. As we have found them they measure from 4 to $5\frac{1}{2}\mu$ long by $2\frac{1}{2}$ to $3\frac{1}{2}\mu$ wide, the most common size being 5 x $3\frac{1}{3}\mu$ (Plate IV, Fig. 1).

The amount of damage that this fungus has done to stored apples is probably not large, but specimens of affected fruit have been received from several different localities, and it is not unlikely that it has caused some loss in many storage houses and fruit cellars in Western New York.

We have found it on but two varieties, Baldwin and Rhode Island Greening. However, inoculations proved that it would grow as readily on other varieties as upon these two.

Artificial inoculations of the fungus on apples and pears were made to prove its parasitism. In all of the inoculations the characteristic rot always developed, while check fruits kept under parallel conditions always remained sound.

Only sound, perfect specimens of fruits were used for inoculation experiments. They were immersed in a 1-1000 solution of corrosive sublimate to destroy any spores that might be present. This was washed off with distilled water and the surplus water absorbed with a piece of sterilized cotton. Two fruits of the same variety were placed in a large moist chamber that had been washed out with a 1-1000 solution of corrosive sublimate. The epidermis of each fruit was punctured with a sterilized needle and some of the fungus growing pure on bean stems, potato agar or

apple agar was placed in the puncture of one fruit, the other being reserved for the check. (Plate V.)

TABLE I.—INOCULATION ON FRUIT WITH PURE CULTURES OF *Hypochnus* SPECIES.

ON APPLES.

Date of inoculation.	Variety.	Date of examination.	Diameter of decayed spot at point of inoculation.	Condition of check.
Mar. 7...	R. I. Greening....................	Mar. 16....	5 MM..	Sound.
" 7...	" "	" 16....	3½ "	"
" 16...	Holland........................	" 23....	10 "	"
" 16...	Baldwin........................	" 23....	5 "	"
" 16...	Boiken.........................	" 23....	6 "	"
" 16...	Pewaukee.......................	" 23....	8 "	"
" 16...	R. I. Greening.................	" 23....	7 "	"
" 16...	Paragon........................	" 23....	7 "	"
" 16...	Hubbardston....................	" 23....	6 "	"
" 16...	Ontario........................	" 23....	8 "	"
" 16...	Mann...........................	" 23....	6 "	"
" 16...	Monmouth.......................	" 23....	5½ "	"
" 16...	Northwestern Greening..........	" 23....	8 "	"
" 16...	Rome Beauty....................	" 23....	6 "	"
" 19..	Princess Louise................	" 26....	9 "	"
" 19...	Esopus Spitzenberg.............	" 26....	8 "	"
" 19 ..	Tufts..........................	" 26....	7 "	"
" 19...	Amasia.........................	" 26....	4½ "	"
" 19...	Starbuck.......................	" 26....	5 "	"
" 19...	Stayman........................	" 26....	6 "	"
" 19...	Pumpkin Sweet..................	" 26....	6 "	"
" 19...	Coon Red.......................	" 26....	5½ "	"
" 19...	Thornton.......................	" 26 ...	5 "	"
" 19...	Dickinson......................	" 26....	5 "	"
" 20...	Nelson.........................	" 27....	4 "	"
" 20...	Jones Seedling.................	" 27....	5 "	"
" 20...	Ben Davis......................	" 27....	5 "	"
" 20...	Greenville.....................	" 27....	6 "	"
" 20...	Ontario........................	" 27....	5 "	"
" 20...	Moyer Prize....................	" 27....	5 "	"
" 20...	Moore Sweet....................	" 27....	9 "	"
" 20...	Golden Medal...................	" 27....	9 "	"
" 20...	Hargrave.......................	" 27....	4 "	"
" 20...	Jacob..........................	" 27....	9 "	"
" 20...	Ewalt..........................	" 27....	6 "	"

ON PEARS.

Date of inoculation.	Variety.	Date of examination.	Diameter of decayed spot at point of inoculation.	Condition of check.
April 6...	Bordeaux.......................	April 14...	5MM.	Sound.
" 6...	Pound..........................	" 14...	6 "	"
" 6...	P. Barry.......................	" 14 ..	7 "	"
" 6...	Garber.........................	" 14...	4½ "	"
" 6...	Josepheus de Malines...........	" 14...	8 "	"

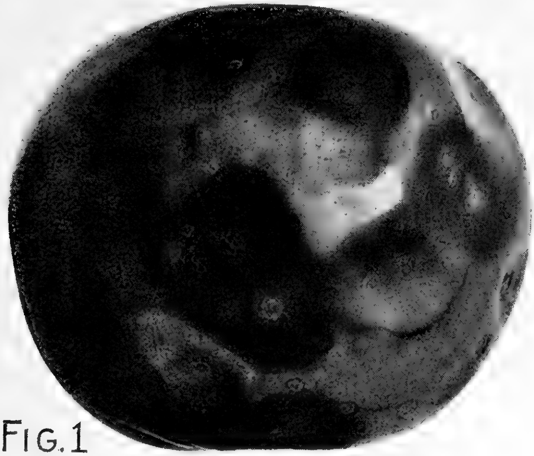

FIG. 1

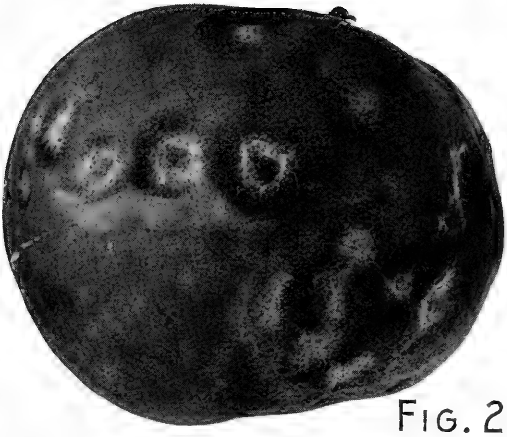

FIG. 2

PLATE III.—GREENING APPLES AFFECTED WITH *Hypochnus* ROT:
FIG. 1, APPEARANCE WHEN REMOVED FROM STORAGE; FIG. 2, DEVELOPMENT OF FUNGUS AFTER THE FRUIT HAS BEEN IN A MOIST CHAMBER A FEW DAYS.

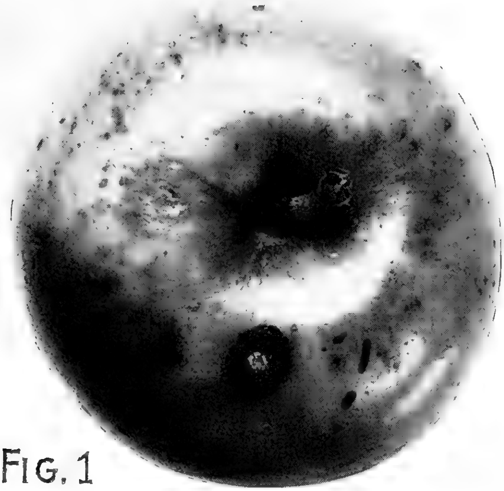

FIG. 1

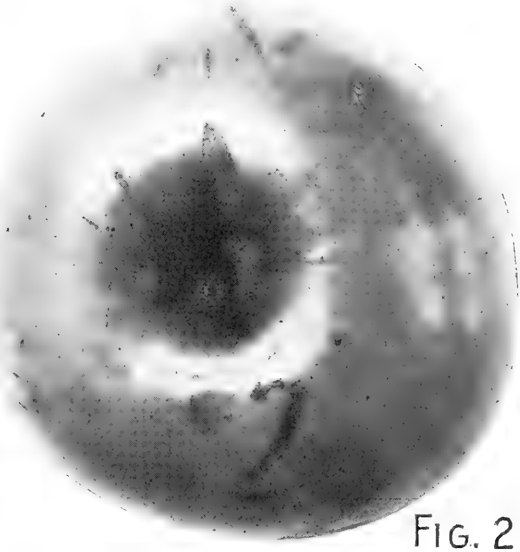

FIG. 2

PLATE V.—ARTIFICIAL INOCULATIONS ON NORTHWESTERN GREENING APPLES:
FIG. 1, TEN DAYS AFTER INOCULATION WITH PURE CULTURE OF *Hypochnus* SPECIES; FIG. 2, CHECK—PUNCTURE TO RIGHT OF "2." NATURAL SIZE.

PLATE VI.—BALDWIN APPLE AFFECTED WITH THE CORE DECAY.

As has been stated the rot always appeared to start in an apple through a rupture in the epidermis caused by scab. It was desirable to know if the fungus could penetrate the unbroken epidermis and cause the rot. To determine this, artificial inoculations were made with the same care and under the same sterile conditions as previously described. Two apples of the same variety were placed in a moist chamber; a bit of the fungus from a pure culture was placed upon one without puncturing or injuring the epidermis in any way. The other fruit was inoculated by puncture as previously described. The rot did not develop in any of the fruits inoculated on unbroken epidermis, though a large surface growth of the fungus appeared, but on all the fruits inoculated through a puncture the rot was produced.

TABLE II.—INOCULATIONS MADE ON SOUND EPIDERMIS AND THROUGH A PUNCTURE.

Date of inoculation.	Variety.	Epidermis.	Date of examination.	Condition.
Mar. 24.	Princess Louise	Sound	Mar. 31.	Fruit sound.
" " .	" "	Punctured.	" " .	Decayed spot, 8mm. in diameter.
" " .	Ben Davis	Sound	" " .	Fruit sound.
" " .	" "	Punctured.	" " .	Decayed spot, 5½mm. in diameter.
" " .	Titus Pippin...	Sound	" " .	Fruit sound.
" " .	" " ...	Punctured	" " .	Decayed spot, 6mm. in diameter.
" " .	Shannon	Sound	" " .	Fruit sound.
" " .	"	Punctured.	" " .	Decayed spot, 5mm. in diameter.
" " .	Baldwin.......	Sound	" " .	Fruit sound.
" " .	"	Punctured.	" " .	Decayed spot, 5mm. in diameter.
" " .	Mann	Sound	" " .	Fruit sound.
" " .	"	Punctured.	" " .	Decayed spot, 7mm. in diameter.
" " .	Stayman	Sound	" " .	Fruit sound.
" " .	"	Punctured.	" " .	Decayed spot, 6mm. in diameter.
" " .	R. I. Greening.	Sound	" " .	Fruit sound.
" " .	" " .	Punctured.	" " .	Decayed spot, 6½mm. in diameter.

The results prove that the fungus is a wound parasite, as the mycelium is entirely unable to penetrate the unbroken epidermis and produce the rot.

That the rot produced by the artificial inoculations was caused by the fungus with which they were made, *Hypochnus* sp., was definitely determined by a microscopic examination, or by making cultures from some of the affected tissue removed under sterile conditions. In most of the examinations both methods were used. In all but two or three cultures the fungus grew absolutely pure.

The fact that only apples affected with scab were attacked by this fungus, as was the case with " Pink Rot," emphasizes more emphatically than ever the great importance of protecting the apple crop from scab by thorough and persistent spraying with bordeaux mixture.

The finding of decayed fruit in several cold storage houses indicates that the low temperature cannot be relied upon to hold the trouble entirely in check, though it is probable that it does retard its development to some degree.

II. A CORE DECAY OF BALDWIN APPLES.

During the past winter our attention was called to a very peculiar decay of Baldwin apples. Outwardly the fruit would appear to be perfectly sound, but upon being cut a part of the tissue surrounding the core was found to be decayed. (Plate VI.)

The decayed tissue, which was brown, dry-rotten and tasteless, was entirely surrounded by sound, healthy tissue of normal quality. This indicated that the trouble was not of fungous origin. However, to determine this point definitely, sections of affected tissue were examined microscopically for fungus hyphae and bacteria, but none could be found. Petri dishes containing neutral potato agar were inoculated at several different points with small pieces of the diseased tissue removed under sterile conditions. No growth appeared at any of the points of inoculation, and it was very evident that the trouble was not caused by fungi or bacteria.

Sections of affected tissue were tested with a solution of iodine for starch, but none was found, indicating that the tissue had ripened properly and the decay had developed subsequently.

The trouble was first discovered in apples that were undersized and poorly colored, and affected specimens were usually poor in flavor. A little later first class fruit was examined and found to be affected.

An effort was made to determine if there was any correlation of the size, color or flavor of the fruit with the core decay. Quantities of apples of different sizes and degrees of coloring were examined, but in all cases the decay was found. There was no difference in the size of the decayed area whether the

fruit was large and highly colored, or small and poorly colored, or the quality good or bad.

In a large fruit there was as often a small affected area as a large one, and in apples below the average size there was no constancy of the size of the affected area. But in no case did the decay ever extend outside the core line.

The conditions of ordinary storage under which the apples were kept seemed to have no relation to the decay nor to influence it. Fruit from dry and well ventilated houses was as badly affected as that from damp and poorly ventilated cellars. But fruit kept in cold storage houses was found to be entirely free from the trouble.

In the Station orchard there are certain Baldwin apple trees that have been fertilized with phosphoric acid for the two seasons of 1901 and 1902, and trees in the adjoining row that have not been fertilized with anything during the same period. A comparison of the fruit from these trees gave a good opportunity to determine if the fertilizer had any influence on the trouble. Quantities of apples from the trees that each year had been fertilized with 8 lbs. 7 ounces of South Carolina rock per tree were examined and in practically every case found to have the decay. To compare with these quantities of apples from the trees that had not been given any fertilizer were examined and the decay found in every case. Apples from other trees in the same orchard that had been fertilized with 9 lbs. of South Carolina rock to each tree for several years were examined and the decay found in practically every case.

All of these apples were harvested and put in the Station storage house on the same day, and were under parallel conditions at all times.

The constant presence of the decay in all of these apples indicates that the use of phosphoric acid as a fertilizer had no influence one way or the other upon the trouble.

It was stated by experienced apple dealers that the trouble was confined to fruit grown upon sandy soil, but we have found it as marked in apples grown on a stiff heavy clay as in those grown in a loose, light, sandy soil.

It has also been suggested that the decay is a result of improper ripening as is the case when a tree overbears. But as the trouble

was found to occur in large, highly colored and fully ripe apples with the same constancy as in small and poorly colored ones there seems to be no reason for believing the trouble due to this cause. Overbearing, however, may have some connection with, or be responsible for it. The crop of Baldwin apples in 1902 was excessively large and many trees overbore and this, possibly, is an explanation of the trouble. Then too the season of 1902 was an unusually wet one, and it may be that the excessive moisture, in addition to the overbearing, was responsible for the decay.

The fact that there is no record of a previous trouble of this kind with Baldwin apples tends to strengthen the theory that it was due to the peculiar season. But why it should be so constant in Baldwin apples and absent in the other prominent varieties is not understood.

The fruit spot of the Baldwin apple[2] is well known and in some seasons a serious trouble. Like this core decay the cause is not known, but it has been definitely determined that it is not fungi or bacteria. During the season of 1902 there was none of it in western New York, which seems to indicate that the conditions, whatever they may be, that favor its development are not the same that favor the development of the core decay.

Why this decay should be so constant in Baldwin apples and absent in the other prominent varieties we are unable to say. It was not, however, confined entirely to Baldwin apples. One hundred and twenty-two different varieties of apples, stored under the same conditions in the Station storage house were examined and specimens of Cox Pomona, Jacob, Jones Seedling, Northwest Greening, Esopus Spitzenberg, Wolf River and Peck Pleasant were found that showed the decay in varying degrees.

While the trouble appears to be one peculiar to the season, it is very clear that the conditions of storage exerted a pronounced influence on checking the decay. On April 11 and again on June 4—within a week of the end of the apple season—quantities of Baldwin apples of different grades that had been in cold storage (30 and 32° F.) since October were examined and not a single affected specimen found, while apples of the same variety under various conditions of ordinary storage invariably showed marked cases of the trouble.

[2] For a description of this trouble see Bulletin No. 164, p. 215, of this Station.

POTATO SPRAYING EXPERIMENTS IN 1903.*

F. C. STEWART, H. J. EUSTACE AND F. A. SIRRINE

SUMMARY.

This bulletin gives the results of the second year's work on the ten-year potato spraying experiments begun in 1902; also, an account of six business experiments conducted by farmers.

The results of the ten-year experiments for 1903 are as follows:

At Geneva, the rows sprayed three times yielded at the rate of 262 bushels per acre; those sprayed five times, 292, and those not sprayed, 174. Thus, three sprayings increased the yield 88 bushels per acre, and five sprayings 118 bushels. The increase in yield on the sprayed rows was due, almost wholly, to the better protection against late blight.

On Long Island the rows sprayed three times yielded at the rate of 246½ bushels per acre; those sprayed five times 263, and those not sprayed 207. The increased yield due to three sprayings was 39½ bushels per acre, while that due to five sprayings amounted to 56 bushels per acre. The increase in yield was due, chiefly, to better protection against late blight and flea-beetles.

The farmers' business experiments were designed to determine the actual profit in spraying potatoes under ordinary farm conditions. The increase in yield was determined and an account kept of all expense. Late blight being destructive, the spraying proved highly profitable. On the total area of 61 1-6 acres sprayed in the six experiments in different parts of the State

*Reprint of Bulletin No. 241.

there was a total increase in yield of 3,746 bushels, or an average of 61.24+ bushels per acre. At 50 cents per bushel the increase was worth $1,873. Subtracting from this amount the total expense of the spraying, $296.49, there is a remainder of $1,576.51, which is the total net profit. This is at the rate of $25.77+ per acre.

It is estimated that the loss from potato blight in New York in 1903 was 50 bushels per acre on the average. Since the area devoted to potatoes in the State is about 396,000 acres and the average price of potatoes in the fall of 1903 was 50 cents per bushel, the total loss sustained by New York farmers in a single season was nearly $10,000,000. A large part of this loss might have been prevented by spraying.

INTRODUCTION.

During the past season the Station has continued the ten-year potato-spraying experiments begun in 1902. These experiments are designed to determine how much the yield of potatoes can be increased, on the average, by spraying with bordeaux mixture. The plan is to continue the experiments during ten consecutive seasons, and take the average increase in yield as the index of the value of spraying potatoes in New York State. The experiments[1] are to be conducted in two localities, namely, at Geneva and at Riverhead. Two methods of spraying are to be compared as to their efficiency: Some rows are sprayed every two weeks regularly, while others are sprayed only three times during the season. At each place the area of the experiment field is to be three-tenths of an acre each season. The rows sprayed every two weeks alternate with those sprayed only three times and with others not sprayed at all. For further details see Bulletin 221.

In addition to the above experiments the Station has, during

[1] A full account of the experiments and the results obtained in 1902 are given in Bulletin 221 of this Station.

the season of 1903, coöperated with five farmers in making experiments designed to determine the net profit in spraying potatoes in different ways under ordinary farm conditions.

SUMMARY OF RESULTS OBTAINED IN TEN-YEAR EXPERIMENTS IN 1902.

TABLE I.—YIELD BY SERIES AT GENEVA IN 1902.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7 and 13.	July 10, 23 and Aug. 12.	317	41
II	2, 5, 8 and 14.	June 25, July 10, 23, 30, Aug. 12, 26 and Sept. 10.	342	36
III	3, 6, 9 and 15.	Not sprayed.	219	4

Gain due to spraying three times 98½ bushels per acre.

Gain due to spraying seven times 123½ bushels per acre.

TABLE II.—YIELD BY SERIES AT RIVERHEAD IN 1902.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	2, 5, 8 and 11.	May 26, June 20 and July 22.	295	20
II	1, 4, 7 and 10.	May 26, June 3, 20, 30, July 11, 23 and Aug. 5.	312	35
III	3, 6, 9 and 12.	Not sprayed.	267	40

Gain due to spraying three times 27⅔ bushels per acre.

Gain due to spraying seven times 45 bushels per acre.

DETAILS OF TEN-YEAR EXPERIMENTS IN 1903.

FITTING, PLANTING, CULTIVATION, ETC.

At Geneva.—The land used was a thinly seeded clover sod. It was plowed May 21, 1903. Owing to severe drought the growth of clover was light; and the soil, being a heavy clay loam, turned up in large, dry, hard lumps which were difficult to pulverize. On May 25 it was fitted by going over it four times with a spring

tooth harrow and clod-crusher. Even after this treatment the soil was lumpy and poorly fitted.

The rows were marked out three feet apart and the furrows opened with a plow. Fertilizer,[2] at the rate of 1,000 pounds per acre was scattered in the furrows. Planting was done May 25 and 26, care being taken to place the seed pieces exactly 15 inches apart in the row. They were covered four inches deep by means of hoes.

The seed was of the variety Rural New Yorker No. 2 and had been selected from the sprayed rows in the experiment of 1902. A few days before planting time the seed tubers were given the formalin treatment[3] for scab and then cut into pieces of the size of a hen's egg without regard to the number of eyes except that each piece bore at least one eye.

During the season the plants were hoed once and cultivated three times. After the last cultivation they were hilled, moderately, with a shovel plow.

The soil was a heavy clay loam with some gravel in it. The field sloped rapidly toward the north giving good surface drainage.

At Riverhead.—The previous crop was cauliflower over the north half of the field and an asparagus seed-bed over the south half. The land was plowed 6 to 8 inches deep April 28 and harrowed twice. After treatment with formalin for scab, planting was done by hand on April 29 with pieces of hen's egg size, placed 15 inches apart in the row and the rows 3 feet apart. The seed used was of the variety Carman No. 1 taken from the sprayed rows in the experiment of 1902.

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[2] South Carolina rock 555 lbs. and ground blood (10 per ct.) 445 lbs.

[3] Tubers soaked two hours in a solution containing one pint of formalin in 30 gallons of water.

The trenches for planting were opened with a double mold-board plow. Home-mixed fertilizer having the formula 4-12-4 and costing $26 per ton was sown in these trenches by hand at the rate of 1,000 pounds per acre. Before planting, the fertilizer was mixed with the soil by running through the trenches a broad shovel attached to a one-horse cultivator. The seed pieces were covered to a depth of 3 to 5 inches by means of the same one-horse cultivator with side hoes attached. Afterward the rows were levelled off by harrowing.

Further cultivation consisted of two harrowings (one three days before, and the other five days after, the plants came up), one cross working with a Hallock weeder, one hand hoeing to remove volunteer asparagus, and four cultivations (one deep, three shallow) with a horse cultivator. The plants were not hilled. The soil was of practically the same character as that used in 1902, namely, a well-drained sandy loam containing some gravel.

PREPARATION AND APPLICATION OF THE BORDEAUX MIXTURE.

Both at Geneva and at Riverhead the bordeaux mixture used was of the 1-to-8 formula the same as in 1902. At Geneva it was applied with a knapsack sprayer and very thoroughly. Again it was found almost impossible to spray the rows of Series I and II without getting some of the mixture on the unsprayed rows of Series III.

At Riverhead, the rows in Series I (to be sprayed three times) were sprayed with a horse machine carrying five Vermorel nozzles per row and applying the bordeaux at the rate of 100 gallons per acre. The rows in Series II (to be sprayed every two weeks) were given three sprayings with the same machine and on the same dates as for Series I. The additional two sprayings given Series II were made with a knapsack sprayer.

DATES OF SPRAYING.

At Geneva: Series I.—This series, consisting of rows 1, 4, 7, 10, and 13, was sprayed three times with bordeaux mixture—July 14, 28 and August 26. The first spraying, July 14, was necessitated by the appearance of " bugs " in injurious numbers. At this time the plants were about a foot high. To poison the " bugs " white arsenic was used with the bordeaux in the proportion of one quart of the stock solution[4] to 50 gallons of bordeaux. Three days later there were to be seen only a few " bugs " and no evidence that the arsenic had injured the foliage.

On July 28 a second brood of " bugs " appeared and it was deemed advisable to poison them. Moreover, the weather was favorable to late blight. Accordingly, a second spraying of the rows in this series was made July 28 with bordeaux and white arsenic mixed in the same proportions as in the previous spraying. Again the " bugs " were killed without any injury to the foliage and there was no further trouble with them during the season.

The third and last spraying on this series was made August 26 with bordeaux alone. Since there were no " bugs " it was unnecessary to use poison. It appears that this was a time when the rows in this series were much in need of spraying for protection against late blight. They had not been sprayed for four weeks and no bordeaux was to be seen upon them. During the previous three or four days the weather had been wet and " muggy." In some fields northwest of Geneva there was already considerable blight. It was also abundant in a patch of early potatoes a few rods from the experiment and there were even traces of the disease all along the

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[4] Formula for stock solution of white arsenic:

2 lbs. white arsenic.
8 lbs. salsoda (washing soda).
2 gallons water.

Boil until dissolved. As a poison, one pound of white arsenic is equal to two pounds of paris green.

unsprayed rows in the experiment field. Undoubtedly, it was this third spraying which gave Series I its protection against late blight. Probably the results would have been better if it had been made two or three days earlier.

Series II.—This series consisted of rows 2, 5, 8, 11 and 14. The plants were sprayed five times—July 7, 21, August 7, 21 and September 3. At the time of the first spraying the plants were six to eight inches high. On this series it was necessary to use poison[5] but once, namely, in the second spraying, July 21. The early spraying of July 7 seems to have discouraged the "bugs" so that as late as July 21 there were but few of them on this series, although they were abundant on the other two unsprayed series a week earlier. Two days after spraying with bordeaux and white arsenic there were no live "bugs" and no injury to the foliage.

Up to the time of the fourth spraying, August 21, no trace of late blight had been found anywhere in the experiment field, but it made its appearance three days later. The fifth spraying, September 3, was made while the blight epidemic was at its height. According to our plan for spraying this series regularly every two weeks a sixth spraying should have been made September 17, but the plants were so much blighted that it was thought it would not pay to spray them again.

Series III.—Series III consisted of rows 3, 6, 9, 12 and 15. They were not sprayed at all with bordeaux but were treated twice (July 14 and 28) with white arsenic in lime water to kill the "bugs." The white arsenic was used at the same rate as on Series I and II; that is, one quart of stock solution to 50 gallons of lime water.

Three days after the first treatment nearly all of the plants showed slight injury. It appears that too little lime was used with the arsenic. The quantity was not measured, but guessed at, and was thought to be ample. In the second treatment care was taken to

[5] White arsenic, one quart stock solution to 50 gallons of bordeaux.

use an abundance of lime and no injury resulted. In both treatments the "bugs" were practically all killed.

At Riverhead: Series I.—This series consisted of four rows[6]—Nos. 1, 4, 7 and 10, which were sprayed with bordeaux mixture three times; namely, on June 5, July 22 and August 7. Poison (white arsenic) was used in all three sprayings at the rate of one pint of the stock solution[7] to 50 gallons of bordeaux.

Series II.—This series consisted of four rows—Nos. 2, 5, 8 and 11. They were sprayed with bordeaux mixture five times; namely, on June 5, 24, July 7, 22 and August 7. As on Series I, poison was used with every application. Perhaps it was unnecessary to use poison so frequently, but as there were always a few flea-beetles and a few "bugs" and the poison cost so little it was thought best.

Series III.—Series III, also, consisted of four rows,—Nos. 3, 6, 9 and 12. The rows of this series were not sprayed at all with bordeaux, but when the "bugs" appeared in destructive numbers (July 7) they were promptly treated with white arsenic, one pint of the stock solution in 50 gallons of lime water. This one treatment freed the plants from "bugs" and there was no further trouble with them.

THE RESULTS OF THE TEN-YEAR EXPERIMENTS.

AS INDICATED BY THE CONDITION OF THE FOLIAGE.

At Geneva.—Potato bugs did no appreciable damage to any of the plats. Twice they appeared in considerable numbers, but were promptly killed before they did any damage. Although poison was used with the bordeaux but once on the rows in Series II, "bugs" were less numerous on this series than on Series I where it was neces-

[6] It may be observed that the rows here given for Series I are not the same as those given in Bulletin 221, p. 244. This change is the result of a rearrangement which was made for the purpose of bringing the rows in each series into the same order as in the experiment at Geneva.

[7] For formula see footnote on page 256.

sary to use the poison twice. On July 14 young "bugs" were so numerous on Series I and III, that it was absolutely necessary to poison them to prevent serious injury to the plants. At the same time there were but a few on Series II, and even a week later there were so few that it was a question whether it was worth while to poison them.

The explanation of this seems to be the fact that Series II was sprayed with bordeaux a week earlier than Series I and some of the young "bugs," which were hatching about that time, were killed by feeding on the heavily-sprayed foliage. It is unlikely that they migrated to the unsprayed plants because they were too young to migrate. Similar observations were made in 1902 but interpreted differently. (See Bul. 221, p. 245.) Whatever the true explanation of it may be the fact is established that plants thoroughly sprayed with bordeaux mixture are much freer from "bugs" than are unsprayed plants.

About July 10 flea-beetles were quite numerous for a few days and again about September 1 they were considerably in evidence, but at no time did they materially injure the plants. However, their work was more noticeable on the unsprayed than on the sprayed plants.

There was no injury whatever from early blight, *Alternaria solani* and certainly none from drought. Nevertheless, some of the plants on all the rows were slightly affected with a browning of the leaf margins, the cause of which we were unable to determine. This was first observed July 11 before the plants were a foot high and continued to be noticeable throughout the season. The leaves were slightly curled and the margins brown. The worst-affected plants died prematurely. The damage done was not great anywhere and was least on the rows sprayed every two weeks. It could not have been due to arsenic injury because it appeared before any arsenic had been used. There was, however, slight arsenic injury on the

rows in Series III resulting from the first application of arsenic in lime water July 14. (See page 123).

Although carefully watched for, no trace of late blight, *Phytophthora infestans,* was found in the experiment field until August 24. Up to this time the sprayed rows were no better than the unsprayed except that they showed somewhat less injury from the unknown tipburn. The plants were looking well. In places they met between the rows but the ground was not entirely covered by them. Immediately after its first appearance the blight spread rapidly. It soon became evident that the north (lower) end of the field would suffer most. Not only was the soil here wetter and the air circulation poorer but there was also a small patch of blight-infested early potatoes not more than twenty feet distant.

At the north end, the unsprayed rows had lost a large part of their foliage by September 1, and what remained was badly spotted. There were also a good many points of infection on the rows sprayed three times (Series II) but the rows sprayed every two weeks (Series I) were almost perfect in foliage. At the south end of the field there was little if any contrast in appearance between the sprayed and unsprayed rows, although the latter were slightly affected.

On September 3 the unsprayed rows, at the north end, were pronounced dead.

On September 7, at the north end, the 3-sprayed rows were sufficiently attacked to affect their growth slightly and by September 14 they were dead. The rows sprayed every two weeks lived until September 21. Thus it appears that, at the north end of the field, three sprayings prolonged the life of the plants 11 days while 5 sprayings prolonged it 18 days.

At the south end of the field the 3-sprayed rows outlived the unsprayed by fully three weeks and were finally pronounced dead on October 3; while the rows sprayed every two weeks lingered along until October 7.

At Riverhead.—In the experiment at Riverhead no damage was done by "bugs." They appeared in considerable numbers about July 7 but were promptly poisoned. Flea-beetles were plentiful about June 5 and again about August 14. On the latter date they suddenly appeared in swarms. It seems probable that they migrated to the experiment field from neighboring fields which were killed by blight about that time. The unsprayed rows were already nearly dead from blight and the flea-beetles soon finished the sprayed rows which, at that time, still had about two-thirds of their foliage.

Early blight caused slight damage to the unsprayed plants, but the chief enemy was late blight, *Phytophthora infestans,* which made its first appearance in the experiment field on July 25. In some neighboring fields it had been present since July 15. During the second week in August there was a general epidemic of blight. In the experiment field the unsprayed rows suffered much more than the sprayed although the latter became considerably affected by August 15. The contrast in appearance between the sprayed and unsprayed rows was at no time as great as in 1902 although the increase in yield due to spraying was somewhat greater in 1903 than in 1902.

The unsprayed rows died about August 16 while the sprayed rows continued green several days longer, those of Series II holding out until September 1.

AS SHOWN BY THE YIELD.

At Geneva.—The potatoes were dug by hand October 22 and 23. As in 1902, the product of each row was sorted into two grades, marketable and culls, and the weight of each grade taken. All tubers larger than a hen's egg were graded as marketable. The sorting was all done by the writers and as uniformly as possible.

TABLE III.—YIELDS IN THE EXPERIMENT AT GENEVA.

Section.	Row.	Treatment.	Yield per row.		Yield per acre.			
			Marketable.	Culls.	Marketable.		Culls.	
			Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A	1	Sprayed 3 times	309	20	257	30	16	40
	2	Sprayed 5 times	334	19	278	20	15	50
	3	Unsprayed	191	23	159	10	19	10
B	4	Sprayed 3 times	290	17	241	40	14	10
	5	Sprayed 5 times	343	16	285	50	13	20
	6	Unsprayed	210	22	175	00	18	20
C	7	Sprayed 3 times	330	18	275	00	15	00
	8	Sprayed 5 times	346	19	288	20	15	50
	9	Unsprayed	205	22	170	50	18	20
D	10	Sprayed 3 times	314	17	261	40	14	10
	11	Sprayed 5 times	360	19	300	00	15	50
	12	Unsprayed	212	24	176	40	20	00
E	13	Sprayed 3 times	329	16	274	10	13	20
	14	Sprayed 5 times	370	22	308	20	18	20
	15	Unsprayed	228	22	190	00	18	20

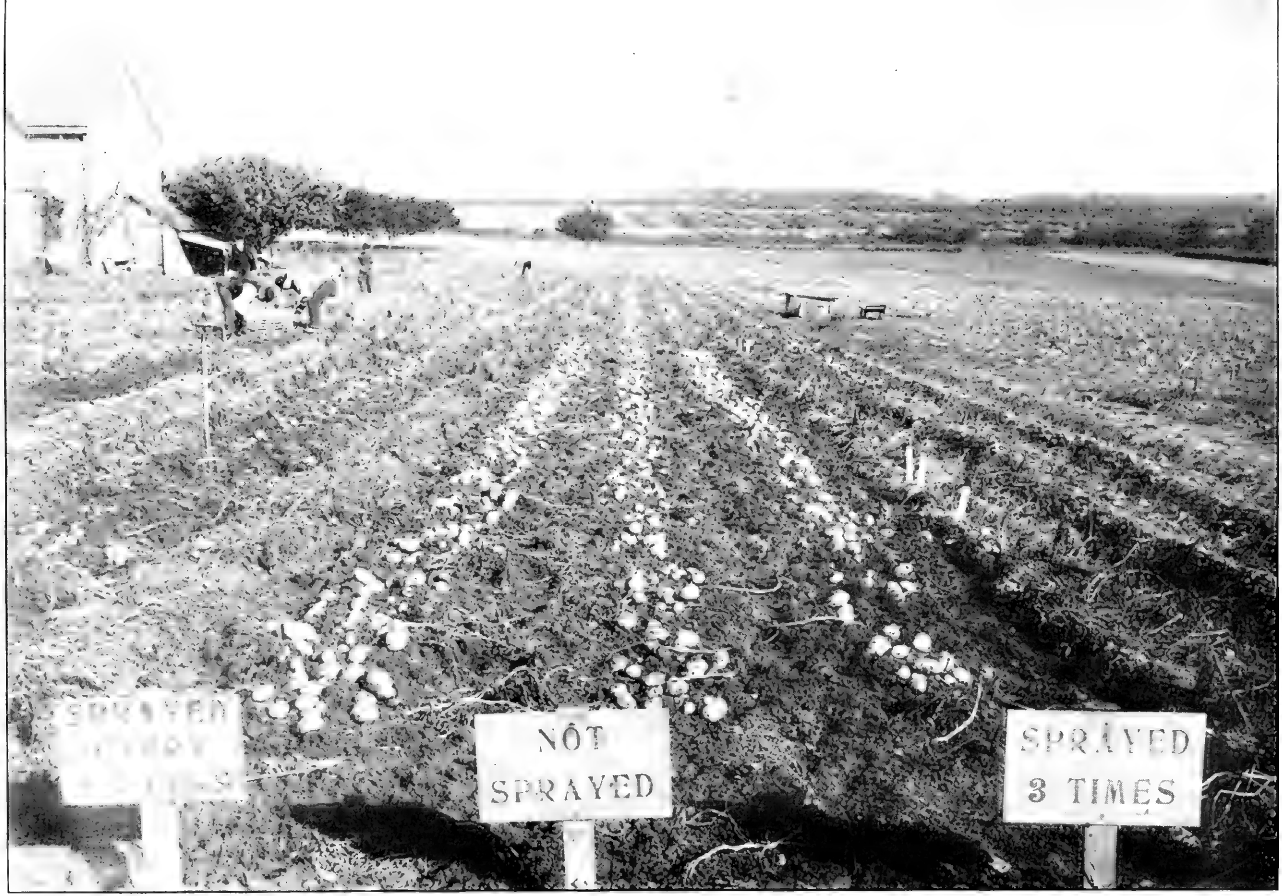
Comments on the table.—A study of the above table reveals the following: (1) In each of the five sections the five-sprayed row yielded more than the three-sprayed row, the difference varying from 13 to 44 bushels per acre.

(2) In each section the sprayed rows yielded more than the unsprayed row, the difference between the five-sprayed row and the adjacent unsprayed row varying from 110 to 124 bushels per acre.

(3) In different sections the yield of rows treated in the same way varied considerably. The yield of the unsprayed rows varied from 159 to 190 bushels per acre; on the three-sprayed rows it varied from 241 to 275 bushels per acre; and on the five-sprayed rows, from 278 to 308 bushels. This variation is partly due to the fact that blight was more severe on the west side of the field than on the east, and partly to slight variations in soil in different parts of the field. It is impossible to avoid such variations entirely, but by alternating the sprayed with the

Plate VII.—The Experiment Field at Geneva.
(Photographed Sept. 16.)

Plate VIII.—Rows 11, 12 and 13 in Experiment at Geneva.
(Photographed Sept. 16.)



Per acre:—300 bu.; 177 bu.; 274 bu.

PLATE IX.—ROWS 11, 12 AND 13 IN EXPERIMENT AT GENEVA.
(See page 128.)

29.2 bu. 17.4 bu. 26.2 bu.

PLATE X.—TOTAL YIELD IN EXPERIMENT AT GENEVA.

unsprayed rows as in this experiment they have little influence on the results. The difference between the average of the five unsprayed rows and the average yield of the five rows sprayed five times may be safely taken as the result of the spraying.

Yield by series.—The five rows sprayed three times constitute Series I and the average yield of these five rows make the yield of Series I. The yields given for Series II and III have been computed in the same manner. The yield by series is shown in the following table:—

TABLE IV.—YIELD BY SERIES AT GENEVA.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13	June 5, July 22 and Aug 7.	262	—
II	2, 5, 8, 11 and 14	June 5, 24, July 7, 22 and Aug. 7.	292	10
III	3, 6, 9, 12 and 15	Not sprayed.	174	20

Increase in yield due to spraying three times, 88 bushels per acre.
Increase in yield due to spraying five times, 118 bushels per acre.

The difference in the appearance of the foliage on Series I and II, although somewhat greater than in 1902, was, nevertheless, quite small and seemed insufficient for a difference in yield of 30 bushels per acre.

The impossibility of correctly estimating differences in yield by the eye is shown even more strikingly in Plate IX, which is from a photograph of Rows 11, 12 and 13 as the tubers lay on the ground after digging. The average observer would say that the yield on the row sprayed every two weeks was certainly somewhat greater than that on the unsprayed row, and that, probably, the row sprayed three times would outyield the unsprayed row by a few bushels per acre; but only one having much experience in making such estimates would expect to find the differences anything like as great as they really were. As a matter of fact the row sprayed every two weeks outyielded the unsprayed row by 123 bushels per acre; and the row

sprayed three times outyielded it by 97 bushels per acre. (See table on page 128.) The explanation of the matter is this:—On the unsprayed row there were nearly as many tubers as on the sprayed rows, but each tuber was a little smaller. The eye notes the number of tubers rather than their size. The only fair way to determine the increase in yield in spraying experiments is to weigh or measure the tubers.

Loss from rot.—In spite of the severe attack of late blight (*Phytophthora*) on the unsprayed rows there was only a small amount of rot among the tubers. There seems to have been less rot than in 1902 when it was estimated to be 7.6 per ct.[8] The increased yield on the sprayed rows was due chiefly to the prolongation of the life of the plants and to only a small extent to the prevention of rot.

At Riverhead.—The potatoes were dug on September 8 and sorted into two grades, marketable tubers and culls, in the same manner as at Geneva.

TABLE V.—YIELDS IN THE EXPERIMENT AT RIVERHEAD.

Section.	Row.	Treatment.	Yield per row.				Yield per acre.			
			Marketable.		Culls.		Marketable.		Culls.	
			Lbs.	*oz.*	*Lbs.*	*oz.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
A	1	Sprayed 3 times	345	00	69	00	230	00	46	00
	2	Sprayed 5 times	360	00	81	4	240	00	54	10
	3	Unsprayed	300	12	70	12	200	30	47	10
B	4	Sprayed 3 times	341	00	46	12	227	20	31	10
	5	Sprayed 5 times	394	00	70	8	262	40	47	00
	6	Unsprayed	289	4	70	00	192	50	46	40
C	7	Sprayed 3 times	396	12	55	8	264	30	37	00
	8	Sprayed 5 times	388	00	72	00	258	40	48	00
	9	Unsprayed	296	8	65	8	197	40	43	40
D	10	Sprayed 3 times	397	12	43	4	265	10	28	50
	11	Sprayed 5 times	437	00	41	8	291	20	27	40
	12	Unsprayed	356	8	47	8	237	40	31	40

[8] See Bulletin 221 of this Station p. 251.

Comments on the table.—Again, as in 1902, the difference in yield between the sprayed and unsprayed rows was much smaller at Riverhead than at Geneva. There was a severe attack of late blight (*Phytophthora*) which was only partially prevented by the spraying, even on the rows sprayed every two weeks. Toward the close of the growing period the plants were attacked by hordes of hungry flea-beetles coming from the neighboring blighted fields. Since the unsprayed rows were already dead, the sprayed rows, alone, suffered from this attack and the death of the plants was undoubtedly hastened. Had it not been for flea-beetles the difference in yield between the sprayed and unsprayed rows would probably have been considerably greater.

In all four sections each of the sprayed rows yielded more than the unsprayed row, and, with one exception, Section C, the row sprayed five times outyielded the row sprayed three times. It is not known how it came about that Row 7 (sprayed three times) yielded six bushels per acre of marketable tubers more than Row 8 (sprayed five times).

Yield by series.—The yield by series is shown in the following table:

Table VI.—Yield by Series at Riverhead.

Series.	Rows.	Dates of Spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7 and 10	June 5, July 22 and Aug. 7.	246	45
II	2, 5, 8 and 11	June 5, 24, July 7, 22 and Aug. 7.	263	10
III	3, 6, 9 and 12	Not sprayed.	207	10

Increase in yield due to spraying three times, 39½ bushels per acre.
Increase in yield due to spraying five times, 56 bushels per acre.

Loss from rot.—Among the tubers from the sprayed rows there was only occasionally one affected with rot. By actual count there were only eight rotten tubers on the four rows of Series

II. On the unsprayed rows the loss from rot was about two per ct.

AS SHOWN BY CHEMICAL ANALYSIS.

In the experiment at Geneva in 1902, fifty consecutive hills from a row sprayed seven times and the same number of hills from an adjacent unsprayed row were analyzed in order to determine whether spraying had affected the chemical composition of the tubers. It was found that the sprayed potatoes contained a larger percentage of dry matter which consisted mostly of starch. (See Bulletin 221, page 254.)

A similar analysis was made in 1903. Fifty hills of potatoes sprayed five times and fifty hills of unsprayed potatoes were selected from the experiment at Geneva and analyzed. Unfortunately, the selection of these hills was neglected until the digging had progressed so far that it was impossible to secure 50 consecutive hills in any of the rows. Instead, it was necessary to take 25 consecutive hills from each of two sprayed rows (Rows 8 and 14) and 25 consecutive hills from each of two unsprayed rows (Rows 3 and 6). Thus the sprayed and unsprayed hills were not taken from adjacent rows. They were taken, however, from the same portion of the field; namely, at the south end, where the blight was least destructive.

The following analysis was made by Mr. F. D. Fuller:

TABLE VII.—CHARACTER AND COMPOSITION OF SPRAYED AND UNSPRAYED POTATOES.

YIELD AND SIZE OF TUBERS.

Treatment.	Number of tubers in 50 hills.			Tubers in one hill.	Total weight of tubers.	Average weight of tubers.
	Merchantable.	Unmerchantable.	Total.			
					Lbs.	*Ozs.*
Sprayed potatoes.	227	61	288	5.76	86.3	4.79
Unsprayed "	148	68	206	4.12	47.4	3.67

COMPOSITION OF TUBERS.

Lab. No.	Treatment.	Water.	Dry matter.	Ash.	Protein.	Nitrogen free compounds.	Starch.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1544	Sprayed potatoes.	79.65	20.35	.95	1.96	17.44	13.99
1543	Unsprayed "	79.70	20.30	.088	2.18	17.24	13.97

As in 1902, the sprayed potatoes yielded more tubers to the hill and the larger average size than the unsprayed; but in chemical composition the difference was so slight as to appear unimportant.

SOME BUSINESS EXPERIMENTS.

OBJECT OF THE EXPERIMENTS.

There are many persons who question the reliability of the results obtained in experiments like the Station ten-year experiments described in this bulletin. They doubt that such results can be obtained in ordinary farm practice. The objections to the experiments are: (1) They are on too small a scale (three-tenths of an acre); (2) the spraying is done more thoroughly than farmers would do it; (3) it is impossible to determine accurately the expense of the spraying; (4) the idea is prevalent that the Station potatoes are given extra good care in order that large yields may be obtained.

These objections were quite fully discussed in Bulletin 221, pages 257-261; but in order to settle the matter and determine the actual profit in spraying potatoes under ordinary farm conditions the following business experiments were made.

PLAN OF THE EXPERIMENTS.

In the spring of 1903 the Station arranged with five farmers in different parts of the State to keep an account of their spraying operations on potatoes. An accurate record was kept of all the expense of the spraying including labor, chemicals and wear on machinery. One or more rows were left unsprayed except that they

were treated with poison to protect them against "bugs." In the fall the tubers on such rows were carefully weighed and the yield compared with that of the same number of adjacent sprayed rows. The spraying and all work connected therewith was done by the farmers themselves and in such manner as they thought best. That is to say, these were farmers' business experiments.

THE JAGGER EXPERIMENT.

This experiment was made by H. A. Jagger, Southampton, Long Island. Thirteen acres of potatoes were sprayed four times at a total expense of $50.91 and the yield was thereby increased by 702 bushels which were sold for $351. The net profit on the operation was $300.09, which is at the rate of $23.08 per acre.

The spraying was done with an outfit consisting of an Eclipse No. 2 spray pump mounted in a 100-gallon tank on a two-wheeled cart hauled by one horse (Plate XI). At each passage five rows were sprayed with two nozzles per row. One man did both the pumping and the driving. The original cost of the spraying outfit was $42: Cart, $15; tank, $9; pump, $10; tubing and nozzles about $8.

Bordeaux mixture (1-to-8⅓ formula) was applied four times—June 15, 27, July 15 and 21—at the rate of about 47 gallons per acre at each spraying.

In the first three sprayings paris green was added to the bordeaux at the rate of two pounds to 50 gallons.

The thirteen acres consisted of two fields—one containing eight acres and the other five acres. Both fields were on the same kind of soil, sandy loam, fertilized and cultivated in the same way and planted with the same variety, Carman No. 1, which is the most popular variety in that section. The five-acre field was about 80 rods from the water supply but the eight-acre field was nearer.

In the five-acre field one row 453 feet long was left unsprayed.

On this row paris green was applied twice with a Leggett powder

gun to prevent injury from "bugs." The yield of marketable tubers on the unsprayed row was 514 pounds which is at the rate of 274 bushels per acre. The adjacent sprayed row yielded 615 pounds which is at the rate of 328 bushels per acre. Thus the increase in yield due to spraying was 54 bushels per acre or a total of 702 bushels on the 13 acres.

The items of expense for spraying 13 acres four times are as follows:

294 lbs. copper sulphate, at 6c	$17 64
80 lbs. paris green, at 18c	14 40
1 barrel lime	1 35
Repairs on spraying outfit	1 50
45 hours labor for man, at 20c	9 00
45 hours labor for horse, at 10c	4 50
Interest on investment ($42) at 6%	2 52
Total	$50 91

The average cost per acre of each spraying was 98 cents.

This experiment was conducted throughout by Mr. Jagger. When the fields were visited by one of the writers on August 13 the unsprayed row had already lost about three-fourths of its foliage from late blight, *Phytophthora infestans.* The sprayed portion of the field was still very green and only slightly injured, but Phytophthora was plentiful among the plants. At this time nearly all unsprayed potato fields in the vicinity were dead and brown. Some farmers who were digging and marketing their crops reported only traces of rot. However, a few days later there was considerable rot. In some fields as much as two-thirds of the crop rotted.

Mr. Jagger reports that there was some rot all over his sprayed fields, but it was much worse on the unsprayed row. It is likely that more thorough spraying would have resulted in a considerably larger yield on the sprayed fields.

SALISBURY EXPERIMENT NO. I.

This experiment was made by J. V. Salisbury & Sons, Phelps, N. Y. Ten acres of potatoes were sprayed five times, on the following dates:—July 24, August 8, 26, September 1 and 5. One row 1223 feet long was left unsprayed. The adjacent row on each side of the unsprayed row was sprayed only once; namely, in the first spraying. (See diagram on page 138.)

The spraying was done with a two-horse power sprayer purchased of the Field Force Pump Co., Elmira, N. Y. The list price is $75.00. (Plate XII.) At each passage six rows were sprayed with one Vermorel nozzle per row. The bordeaux used was of the 1-to-8 formula. Poison, white arsenic,[9] was used with the bordeaux only in the first spraying. Paris green was applied to the unsprayed row once, in lime water. The field was about 40 rods from the water supply which was pumped from a well by hand. One man pumped the water and prepared the bordeaux while another did the spraying.

The unsprayed rows[10] began to show the effects of blight (*Phytophthora*) about September 5 and by September 9 there was a marked contrast in appearance between the sprayed and unsprayed rows. By September 12 the unsprayed rows could be recognized at a long distance as a brown streak extending clear across the field. At this time the field as a whole was making a fine appearance although toward the south end there was a spot of perhaps one-fourth acre in which blight had already become thoroughly established. All

[9] Arsenite-of-lime paste was prepared from the white arsenic as follows: 10 pounds of white arsenic and 15 pounds of salsoda (common washing soda) were boiled together in 8 gallons of water until dissolved. The resulting solution was used to slake 20 pounds of quick lime, water being added to make a moist paste. Enough of the paste to contain about one pound of the arsenic was used with 50 gallons of bordeaux.

[10] Rows 4, 5 and 6 of the diagram on page 138. Strictly speaking only Row 5 was an unsprayed row but in this discussion Rows 4 and 6 are also classed as unsprayed rows. The single spraying they received was too early to do them much good.

unsprayed fields in the neighborhood were dead and brown. During the following week the contrast between the sprayed and unsprayed rows become more and more conspicuous until about September 19 at which time the unsprayed rows were dead throughout one-half their length and had only one-fourth to one-third their foliage over the other half. On the same date the adjacent sprayed rows were still quite green except toward the south end where they had lost about one-third their foliage.

On September 28 the north half of the field was in almost full foliage and even as late as October 9 some of the plants here were still quite green. This field continued green fully three weeks longer than unsprayed fields in the same neighborhood.

Nevertheless, over the south half the plants were considerably injured by blight, and there was also considerable loss from rot all over the field, being worst on the unsprayed rows.

There was no damage done by early blight, and flea-beetles caused no damage of any importance. "Bugs" were thoroughly controlled both on the sprayed and unsprayed rows by the one application of poison. The soil was a sandy loam. The potatoes were of two varieties, mixed—Carman No. 3 and Rural New Yorker No. 2. They were planted June 8 to 10.

The method by which the increase in yield was determined can be best explained by the use of a diagram as follows:

DIAGRAM SHOWING METHOD OF DETERMINING THE INCREASE IN YIELD IN SALISBURY EXPERIMENT NO. I.[11]

Row 1 " 2 " 3	Sprayed 5 times.
" 4	Sprayed once.
" 5	Not sprayed.
" 6	Sprayed once.
" 7 " 8 " 9	Sprayed 5 times.

Since Row 5 was the only one which had not been sprayed at all, its yield should be taken as representing what the yield of the field would have been had there been no spraying done. Rows 4 and 6, although badly blighted, were evidently somewhat benefited by the one spraying they received and remained green a little longer than Row 5. Rows 3 and 7 appeared to suffer a little from being next to the badly blighted Rows 4 and 6. For this reason it was thought unfair to use them as representatives of the sprayed portion of the field. Accordingly, one-half the combined yield of Rows 2 and 8 was decided upon as being the proper basis for comparison with the yield of the unsprayed Row 5 for the correct determination of the increase in yield due to spraying.

Row 2 yielded 793 pounds and Row 8, 773 pounds, the average being 783 pounds; while Row 5 yielded only 466 pounds. Thus the increase in yield due to spraying was 317 pounds per row which is at the rate of 62½ bushels per acre. The yield of the sprayed rows

[11] The yields were as follows:

Rows 1 and 3, combined,	1542	lbs.	marketable,	43	lbs.	culls.
Row 2	793	"	"	28	"	"
Rows 4 and 6, combined,	1056	"	"	67	"	"
Row 5	466	"	"	43	"	"
Rows 7 and 9, combined,	1434	"	"	42	"	"
Row 8	773	"	"	33	"	"

Number of rows required to make an acre, 11.872.

was 154 bushels and 55 pounds per acre and of the unsprayed row 92 bushels and 12 pounds.

In order to determine how much Rows 4 and 6 had been benefited by the single spraying given them, the combined yield of these rows was taken and found to be 1056 pounds or 518 pounds each which is greater than the yield of Row 5 by 62 pounds or at the rate of 12 bushels per acre.

In order to determine how much Rows 3 and 7 had been injured by the adjacent blighted Rows 4 and 6 the combined yield of Rows 1 and 3 was compared with the yield of Row 2; and the combined yield of Rows 7 and 9 compared with the yield of Row 8. The combined yield of Rows 1 and 3 was 1542 pounds. Assuming that Row 1 yielded the same as Row 2 the yield of Row 3 must have been 749 pounds or 44 pounds less than the yield of Row 2. Hence, the damage to Row 3 was at the rate of 8⅔ bushels per acre. Likewise, assuming that the yield of Row 9 was the same as that of Row 8 the yield of Row 7 must have been 661 pounds or 112 pounds less than the yield of Row 8. Hence the damage to Row 7 was at the rate of 22 bushels per acre. These figures are of considerable interest because they show the unfairness of comparing the yield of an unsprayed row with that of an adjacent sprayed row. Such a comparison makes the increase in yield due to spraying appear to be considerably less than it really is.[11a]

[11a] Some have expressed the opinion that when a single row in a field is left unsprayed "bugs" and flea-beetles leave the sprayed rows and attack the unsprayed row more severely than they would if no spraying were done. Perhaps this sometimes happens, but we have seen no evidence of it. On the contrary, in four of the business experiments it was very noticeable that the unsprayed rows lived longer and suffered less from blight than did the unsprayed fields in the same neighborhood. Consequently, we believe that the actual gain from spraying was greater than the figures here given show it to be.

The total expense of spraying ten acres five times was $40.07 the items being as follows:

345 lbs. copper sulphate, at 6c.	$20 70
5 bu. lime, at 35c.	1 75
10 lbs. white arsenic, at 5½c.	55
30½ hours labor for man, at 17½c.	5 33
25 hours labor for man, at 15c.	3 75
28½ hours labor for team, at 17½c.	4 99
Wear on sprayer.	3 00
Total	$40 07

The cost of spraying per acre for each application was 80 cents.

The increase in yield due to spraying was 62½ bushels per acre or 625 bushels on ten acres. At the time the potatoes were dug they could have been sold in Phelps at 50 cents per bushel. That is to say, the 625 bushels were worth $312.50. Deducting from this sum the expense of spraying, $40.07, there is left $272.43, which is the net profit on ten acres. This is at the rate of $27.24 per acre.

SALISBURY EXPERIMENT NO. 2.

This experiment, also, was conducted by J. V. Salisbury & Sons, Phelps, N. Y. Fourteen acres of potatoes on sandy soil were sprayed five times with the same outfit and in practically the same way[12] as in the preceding experiment. Seven rows 800 feet long were left unsprayed.

The dates[13] of spraying were as follows: July 23, August 5, 18, September 2 and 8. Poison was used only in the first spraying. The

[12] The only differences worth noting are the following: The work was all done by one man. The water used for making the bordeaux was taken from a spring at one side of the field. Sufficient of the arsenite-of-lime paste (see footnote, page 136) to contain about three-fourths pound of white arsenic was used with 50 gallons of bordeaux.

[13] The dates given are those on which bordeaux was applied to the rows next the unsprayed rows. The spraying of the whole field was not always completed on these dates.

unsprayed rows received an application of paris green in lime water at about the same time.

Although a little late blight (*Phytophthora*) was found on the unsprayed rows on August 27 it was not until September 9 that it began to affect seriously the growth of the plants. By that time it had become thoroughly established throughout the whole length of the unsprayed rows, but was much worse in some places than in others. About one-third the distance across the field from the south end the unsprayed rows ran across a strip of soil which was somewhat different from the rest of the field, being moister, darker in color and less sandy. It was here that the vines grew largest and the blight was most destructive. After crossing this strip of black soil the rows ran up a hillside where the soil was light in color and quite sandy. In this region blight never made rapid progress although it worked steadily among the plants and did them much damage. However, the contrast between the sprayed and unsprayed rows became very marked here. The unsprayed rows took on a sickly, yellowish color. This condition was quite noticeable September 9 and continued to be prominent throughout the season, being most conspicuous about September 15. A great many leaves were quite yellow. No doubt this yellowing was partly the result of blight, but it could not have been wholly due to that cause. Many of the yellow leaves showed no blemish whatever. Moreover, where the unsprayed rows ran across the black, moist soil there was scarcely any yellow foliage although it was here that blight was most virulent.

But, whatever the cause, spraying corrected the trouble. On September 15 when the unsprayed rows were decidedly yellow the sprayed rows adjacent were dark green with scarcely a yellow leaf to be seen. The contrast was very striking. We have frequently observed that the foliage of sprayed plants is darker green than that of unsprayed plants, but have never before seen the difference so marked. We consider this an exceptionally good example of the stimulating effect which bordeaux mixture is believed to have on

potato foliage. Later in the season there was a little yellow foliage among the sprayed plants.

In this field, spraying kept the blight almost completely under control, except on the strip of heavier soil above mentioned and in two other places where a few rows were skipped in one spraying. An examination of this field at any time during the last half of September should have convinced even the most skeptical that spraying, properly managed, will prevent blight. The unsprayed rows were dead and dry while on both sides the sprayed rows were in almost perfect foliage. (Plate XIII.) The sprayed plants remained green so long that it was feared their growth would be cut short by frost, but, fortunately, frost held off unusually late. On October 9 it was estimated that on the average about one-half the foliage on the sprayed plants was still green. This late growth was, doubtless, partly the consequence of the late planting, June 16 to 20, but other fields in the neighborhood planted equally late died nearly a month earlier.

The potatoes were of two varieties, Carman No. 3 and Rural New Yorker No. 2, mixed. There was no early blight, no damage done by flea-beetles, and " bugs " were thoroughly controlled. There was only an occasional rotten tuber even on the unsprayed rows.

The yield of the seven unsprayed rows was 1921 pounds of merchantable tubers which is at the rate of 83 bushels per acre. Seven sprayed rows adjacent yielded 3403 pounds of merchantable tubers or at the rate of 147 bushels per acre. Thus the increase in yield was 64 bushels per acre or 77 per ct. Considering that there was no loss from rot this is a remarkably large increase.

The total expense of spraying the fourteen acres five times was $55.76, the items being as follows:—

504 lbs. copper sulphate, at 6c	$30 24
8 bushels lime, at 35c	2 80
12 lbs. white arsenic, at 5½c	66
55 hours labor for man, at 17½c	9 63
47 hours labor for team, at 17½c	8 23
Wear on sprayer	4 20
Total	$55 76

The cost of spraying per acre, for each application, was 80 cents. Since the increase in yield was at the rate of 64 bushels per acre, the total gain due to spraying 14 acres must have been about 896 bushels of potatoes worth $448. Deducting from this sum the expense of spraying, $55.76, there is left $392.24 which is the net profit on 14 acres. This is at the rate of $28.01 per acre.

From the first of September on, these two Salisbury experiments were visited by the writers every three or four days and full notes on them taken. We regard these experiments as the most instructive ones of the whole series. The conditions under which they were made are fairly representative of the conditions prevailing in the potato growing sections of central and western New York. The yield, 92 and 83 bushels per acre (for the unsprayed rows), are average yields. The sprayer used is one which is upon the market and can be operated by any man of average intelligence. The rate of increase in yield was determined in such a manner that there can be no doubt as to its accuracy and there is good reason to believe that the same rate prevailed througout the whole field in both experiments. The writers, themselves, measured the test rows and superintended the digging and weighing. Mr. Salisbury's statement of the amount of the expense of the spraying is, likewise, to be relied upon. If it is thought that any proof is needed it is found in the fact that he sprayed potatoes for some of his neighbors at 80 cents per acre and furnished everything.

THE WELCH EXPERIMENT.

This experiment was made by Ed. Welch, Phelps, N. Y. A field of 3½ acres of potatoes was sprayed five times with an old two-horse, six-row power sprayer of the same make as that used in the Salisbury experiments. It was bought second hand in 1902 for $10. One row 1235 feet long was left unsprayed. The dates of spraying were: August 1, 8, 21, September 3 and 11. As "bugs" were at no time sufficiently numerous to do damage no poison was used, not even on the unsprayed row. The bordeaux was of the 1-to-8

formula and the water used in its preparation was obtained from a well about 20 rods distant.

Traces of blight appeared in all parts of the field about September 2. Thereafter it made steady progress among both the sprayed and unsprayed plants, being most destructive to the latter. After about September 15 the unsprayed row was noticeably inferior to the rest of the field and could be readily located even at a considerable distance, but the contrast was never as striking as in either of the Salisbury experiments. This may have been because there was but a single unsprayed row, and the plants on the sprayed rows being large somewhat obscured it. Although the spraying did not by any means wholly prevent the blight it held it in check to such an extent that the life of the plants was prolonged far beyond that of plants in unsprayed fields. Over the central portion of the field the plants still had one-third to one-half their foliage on October 3.

The increase in yield was determined in the same manner as in the Salisbury Experiment No. 1; that is, the yield of the unsprayed row was compared with one-half the combined yield of two sprayed rows, the second row on either side of the unsprayed row. This will be better understood by an examination of the accompanying diagram.

DIAGRAM SHOWING METHOD OF DETERMINING THE INCREASE IN YIELD IN WELCH EXPERIMENT.

Row 1	Yield 1028 lbs. Culls 86 lbs.	Sprayed.
" 2	Not weighed.	
" 3	Yield 1006 lbs. Culls 74 lbs.	
" 4	Not weighed.	
" 5	Yield 640 lbs. Culls 137 lbs.	Unsprayed.
" 6	Not weighed.	Sprayed.
" 7	Yield 980 lbs. Culls 82 lbs.	
" 8	Not weighed.	
" 9	Yield 1003 lbs. Culls 71 lbs.	

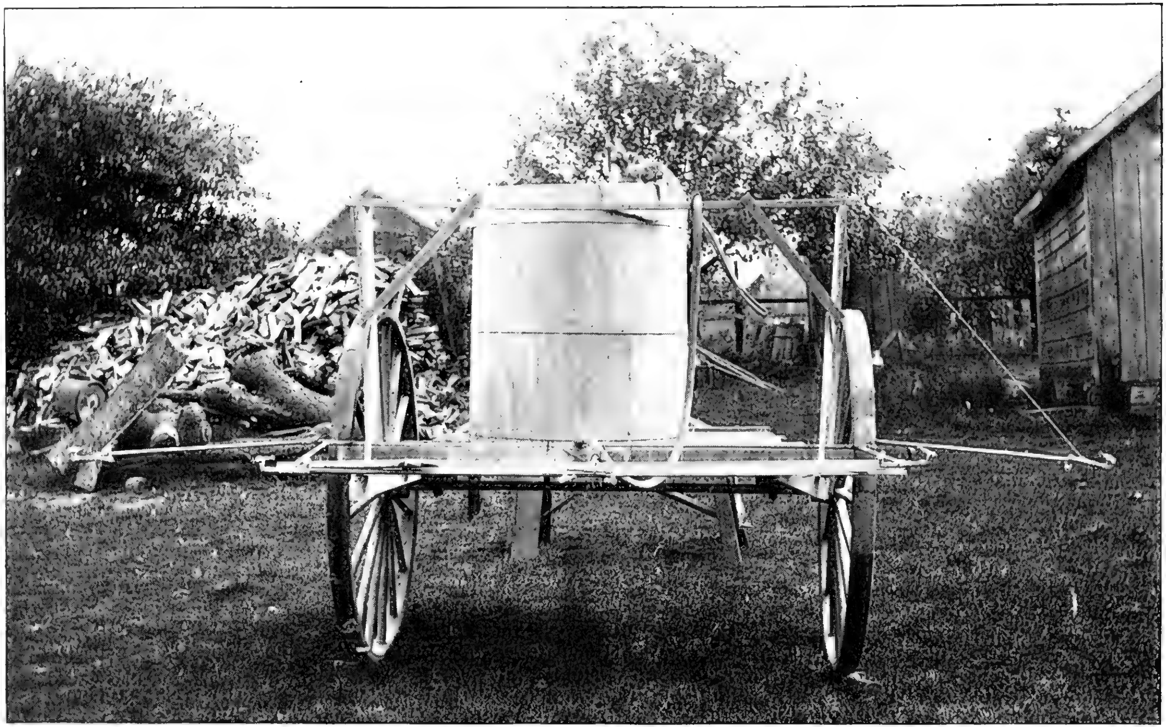


Plate XI.—Outfit Used in the Jagger Experiment.

Plate XII.—Spraying Potatoes in Salisbury Experiment No. 2.

Plate XIII.—Salisbury Experiment No. 2.
(Photographed Oct. 3.)

Plate XIV.—Outfit Used in the Martin Experiment.

PLATE XV.—SPRAYING POTATOES IN THE DOBSON EXPERIMENT.

PLATE XVI.—A BADLY BLIGHTED POTATO PLANT.

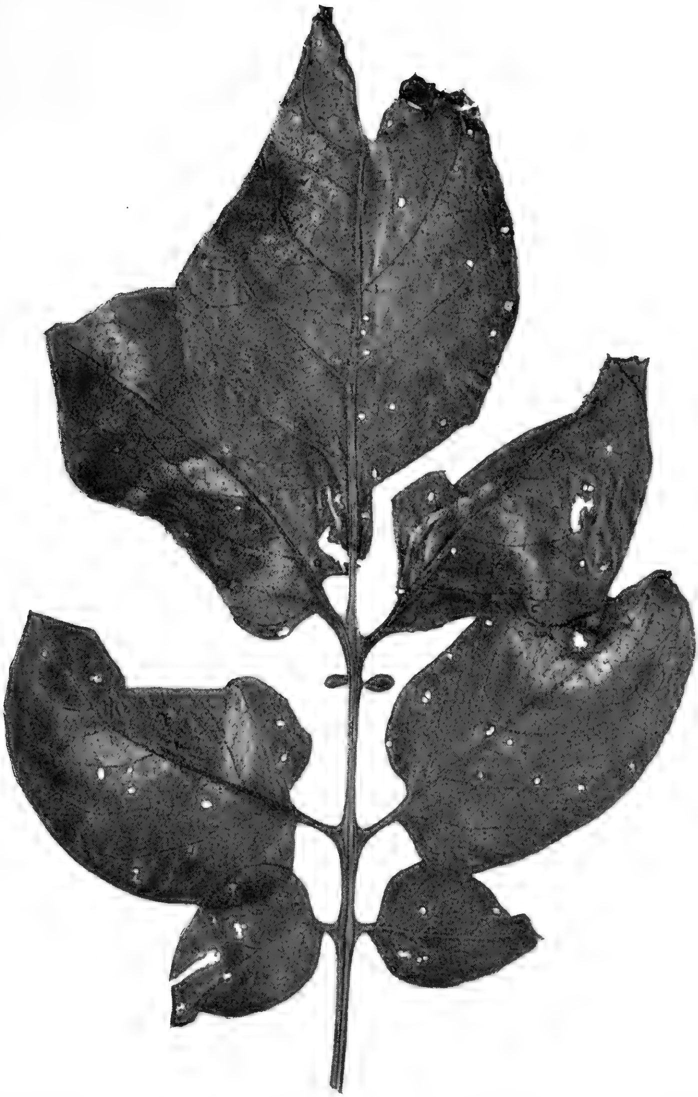


PLATE XVII.—UNDER SURFACE OF POTATO LEAF ATTACKED BY LATE BLIGHT.

One-half the combined yield of Rows 3 and 7 equals 993 pounds which makes the yield of the sprayed rows at the rate of 194 bushels and 37 pounds of marketable tubers per acre; while the yield of the unsprayed row was only 640 pounds or at the rate of 118 bushels and 27 pounds per acre. Hence, the increase in yield was at the rate of 76 bushels per acre.

We wished to obtain the yield of Row 4 for comparison with that of Row 3; also the yield of Row 6 for comparison with Row 7. In this way it could have been determined how much Rows 4 and 6 suffered because of their proximity to the blighted Row 5. But Mr. Welch misunderstood our instructions and took the yield of Rows 1 and 9 instead. It is interesting to note that had these rows been selected to represent the sprayed portion of the field the increase in yield would have been 81½ bushels per acre.

The total expense of spraying these 3½ acres five times was $13.43, the items being as follows:—

94 lbs. copper sulphate, at 6½c.	$6 11
2 bushels lime	32
18 hours labor, man and team	6 00
Repairs on outfit	40
Interest on investment ($10, at 6%)	60
Total	$13 43

The cost of spraying per acre for each application was 77 cents.

As the increase in yield was at the rate of 76 bushels per acre, the total gain due to spraying 3½ acres must have been 266 bushels of potatoes worth $133. Deducting the expense of spraying, $13.43, there is left $119.57 which is the net profit on 3½ acres. This is at the rate of $34.16 per acre.

The soil in the field was a gravelly clay loam. The variety of potato was Carman No. 3.

THE MARTIN EXPERIMENT.

This experiment was made by T. E. Martin, West Rush, Monroe Co., N. Y., about 13 miles south of Rochester. Mr. Martin believes in light applications made frequently. He sprayed 15⅔ acres 16 times and left 2⅓ acres unsprayed.

The unsprayed 2⅓ acres yielded 425 bushels or at the rate of 182 bushels per acre. An exact acre (18 rows) of sprayed plants on either side of the unsprayed yielded 260 bushels, while the total yield of the 15⅔ acres sprayed was 4293 bushels, which is at the rate of 274 bushels per acre. The increase in yield was, therefore, 78 bushels per acre or a total of 1222 bushels on 15⅔ acres.

The total expense of the spraying was $96.32, the items being as follows:—

700 lbs. copper sulphate, at 5½c	$38 50
6 bu. lime, at 25c	1 50
64 lbs. paris green, at 14¼c	9 12
16 days labor for man, at $1.50	24 00
16 days labor for horse, at $1	16 00
Wear on sprayer	7 20
Total	$96 32

Deducting the expense of spraying, $96.32, from the value of the increase in yield,[14] $611, there is left $514.68 net profit on 15⅔ acres or $32.85 per acre.

The sprayer used (Plate XIV) was a one-horse, home-made power sprayer made by overhauling an old Peppler sprayer, using the wheels, axle, thills and barrel and adding the following items: Rumsey double acting force pump, $25; sprocket wheels and chains, $10; steam gauge, $1; relief valve, $1.25; six bordeaux nozzles, $3; gas pipe, fittings, etc., $10; labor, $10; making a total of $60.25.

[14] The bulk of the crop was sold direct from the field at 40 and 45 cents per bushel. In December the price rose to 60 cents per bushel. In order to facilitate comparison the potatoes in the Martin experiment have been valued at 50 cents per bushel as in the other experiments.

At each passage six rows were sprayed, with one nozzle per row, applying bordeaux mixture at the rate of about 22 gallons per acre. In successive sprayings the rows were gone over in opposite directions and the nozzles adjusted so as to spray the plants from both sides and on top. The bordeaux was of the 1-to-8⅓ formula. In the first four sprayings paris green was used with the bordeaux at the rate of four pounds to 50 gallons; but in only one of these sprayings, the second, was the entire 15⅔ acres gone over. On the unsprayed 2⅓ acres paris green was applied twice, July 8 and 13.

The potatoes were of the variety Sir Walter Raleigh. Water for making the bordeaux was obtained from a well 100 rods distant. The cost per acre for each spraying was 39 cents.

This experiment is of special interest because of the large number of sprayings and because the area left unsprayed is unusually large, 2⅓ acres. It ought to satisfy those persons who hold that field experiments should be made on acres instead of on plats. The experiment was carried through entirely by Mr. Martin and the figures are given solely on his authority, but the writers have every reason to believe that the facts are correctly stated.

Mr. Martin informs us that he has carried on similar experiments for several years past, always with profitable results.

THE DOBSON EXPERIMENT.

This experiment was made by Dobson Bros., Charlotte, N. Y., seven miles north of Rochester. The field contained five acres and was planted with three varieties; namely, Michigan Snowflake, Rural New Yorker No. 2 and American Wonder. Two rows, 451 feet long, of each variety were left unsprayed.

The first spraying was made July 21 with bordeaux mixture (1-to-11 formula) and paris green (½ pound to 45 gallons). As some of the "bugs" were not killed, a second spraying with bordeaux and paris green was made a few days later. This time, bordeaux of the 1-to-7⅓ formula was used and paris green added at the rate of one pound to 45 gallons. The "bugs" were then all killed and

there was no further trouble from them. The unsprayed rows were treated with paris green in water, July 22, and the " bugs " all killed.

On September 4 a third spraying with bordeaux alone was given to six rows on either side of the two unsprayed rows of each variety. Thus the field as a whole had but two sprayings while a few rows next the unsprayed rows were sprayed three times.

The sprayings was done with a " Planet " double-acting pump attached to a 50-gallon barrel mounted on a home-made, two-wheeled cart hauled by one horse (Plate XV). A boy did the driving and pumping while two men held each a nozzle at the end of a lead of hose. The cost of this outfit was about $17. Water was obtained from a well about 60 rods distant.

Strange to say there was scarcely any blight (*Phytophthora*) in this field until at the very close of the season. In fact, but few fields in the vicinity were affected to any extent. The soil was a rich, sandy loam. There was a rank growth of vines which completely covered the ground although the hills were three feet apart each way. As late as September 24 the plants still had three-fourths of their foliage and it was impossible to distinguish the unsprayed rows. There was no difference whatever between the sprayed and unsprayed plants. However, Dobson Bros. report that just before the plants died there was a marked difference which could be seen at a long distance.

Under these conditions no marked increase in yield could be expected. The yields are given in the following table:

TABLE VIII.—YIELDS IN THE DOBSON EXPERIMENT.

Variety.	Sprayed.			Unsprayed.			Gain per acre due to spraying.	
	Yield of 2 rows.	Yield per acre.		Yield of 2 rows.	Yield per acre.			
	Lbs.	*Bu.*	*lbs.*	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
Michigan Snowflake......	1063	300	44	1015	287	9	13	35
Rural New Yorker........	981	277	32	975	275	50	1	42
American Wonder........	1059	299	36	1037	293	23	6	13

The average yield of the three varieties was 292 bushels and 37 pounds per acre for the sprayed rows and 285 bushels[15] and 27 pounds for the unsprayed rows, making the increase in yield 7 bushels per acre or 35 bushels on the five acres.

In the first spraying bordeaux was applied at the rate of 81 gallons per acre and in the second spraying 108 gallons per acre. Assuming that the whole field had been sprayed three times and that the cost of the third spraying was the same as for the second the expense account would stand as follows:—

156 lbs. copper sulphate, at 7c.	$10 92
198 lbs. lime	66
102 hours' labor for man, at 15c.	15 30
51 hours' labor for boy, at 7½c.	3 83
51 hours' labor for horse, at 10c.	5 10
16½ lbs. paris green, at 15c.	2 48
Wear on sprayer	1 71
Total	$40 00

Since the total gain due to spraying was only 35 bushels of potatoes worth $17.50, there was a loss of $22.50 which is at the rate of $4.50 per acre. It should be observed, however, that the expense of spraying was unusually large; namely, $2.67 per acre for each application. In the other business experiments reported in this bulletin the cost per acre for each spraying ranged from 39 to 98 cents. With a reasonably large expense for spraying the Dobson field would have paid expenses.

In the Dobson experiment the spraying was done in a business-like manner, but the trouble lies with the method. It is too slow and requires too much man labor. However, had there been a severe attack of blight it is likely that the very thorough spraying would have given results which would have compared very favorably with those obtained in the other experiments.

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[15] Owing to portions of the field being damaged by heavy rains early in the season this average was not maintained throughout the field. The total yield of the five acres was about 1,200 bushels.

THE EXPENSE OF APPLYING PARIS GREEN TO POTATOES.

In some parts of the State, particularly on Long Island, many farmers apply paris green to their potatoes in dry form by means of the Leggett Powder Gun.[16]

Desiring to learn how much it costs to apply poison in this way the Station made arrangements with W. A. Fleet, Cutchogue, Long Island, to keep an account of the expense on his farm.

It should be stated that Mr. Fleet is a successful potato grower and one who does all of his work in a thorough, business-like manner. He has used the Leggett Powder Gun several years and understands its use thoroughly. These statements are made in order that it may be understood that the test reported below is a fair one.

In the season of 1903 Mr. Fleet treated 18 acres of potatoes, eleven acres of early potatoes and seven acres of late ones, with "Green Arsenoid,"[17] for "bugs." The poison was applied in dry form, undiluted, at the rate of about two pounds per acre with a Leggett Powder Gun. On the early potatoes two applications were sufficient. They were made: 1st June 16-25; 2d July 1-8. On the late potatoes a third application was required; namely, on July 15-20. As to the effectiveness of the treatment Mr. Fleet reports as follows:—"The treatment was not thoroughly effective. 'Bugs' were kept in check so they did not eat the vines much, but were not all killed at any one of the three applications." The expense account is as follows:—

84 pounds "Green Arsenoid," at 13½c	$11 34
65 hours' labor, at 15c	9 75
Total	$21 09

The expense per acre for each application was 49 cents.

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16 Manufactured by Leggett & Bro., 301 Pearl St., New York, N. Y.

17 "Green Arsenoid" is a substitute for paris green. Manufactured by the Adler Color & Chemical Works, 100 William St., New York, N. Y. For its chemical analysis see Bulletin 190 of this Station, page 289.

Although "Green Arsenoid" instead of paris green was used in the experiment the results may be accepted as applying equally well to paris green. In poisoning properties "Green Arsenoid" is about equal to paris green and the cost of it is but a little less. At the time of making the arrangements with Mr. Fleet to keep the record we understood that he would use paris green. Mr. Fleet makes no report as to the effect on the foliage. We feel confident that "Green Arsenoid" applied at the rate of two pounds per acre must have injured the foliage. The danger of injuring the foliage is greater with "Green Arsenoid" than with paris green.

SUMMARY OF THE BUSINESS EXPERIMENTS.

The principal features of the six business experiments are shown in the following table:—

TABLE IX.—SHOWING RESULTS OF BUSINESS EXPERIMENTS.

Experiment.	Area sprayed.	Increase in yield per acre.	Total increase in yield.	Cost per A., each spraying.	Total expense of spraying.	Net profit per acre.	Total net profit.
	A.	*Bu.*	*Bu.*				
Jagger	13	54	702	$0.98	$50.91	$23.08	$300.09
Salisbury 1	10	62½	625	.80	40.07	27.24	272.43
Salisbury 2	14	64	896	.80	55.76	28.01	392.24
Welch	3½	76	266	.77	13.43	34.16	119.57
Martin	15⅔	78	1222	.39	96.32	32.85	514.68
Dobson	5	7	35	2.67	40.00	—4.50	—22.50

Total area sprayed, 61⅙ acres.
Total increase in yield, 3,746 bushels.
Average increase in yield per acre, 61.24+ bushels.
Total expense of spraying, $269.49.
Average expense of spraying per acre, $4.84+.
Total net profit, $1,576.51.
Average net profit per acre, $25.77+.

SPRAYING AS CROP INSURANCE.

It is sometimes stated that spraying is, in effect, crop insurance; and since blight is not destructive every season many farmers doubt that it pays to insure in this way. With this idea in mind it is instructive to make calculations like the following:

If, in the Jagger experiment, we subtract from the total expense of the spraying, $50.91, the amount of the probable expense necessary to control "bugs;" namely, $18.90, there is left $32.01 which is the actual extra expense of using bordeaux 4 times. Now, if we divide the total net profit, $300.09 by $32.01 we get as a quotient 9+ which is the number of years Mr. Jagger can spray the same area in potatoes without incurring loss even though no increase in yield is obtained during that time.

In the same manner it can be shown that in the Salisbury experiment No. 1 enough clear money was made to insure against loss during the next 7+ years; in the Salisbury experiment No. 2, 7+ years; in the next 7+ years; in the Salisbury experiment No. 2, 7+ years; in the Welch experiment, 8+ years; and in the Martin experiment, 6+ years.

CAUSES OF FAILURE.

Because of the heavy loss from blight in 1902 an unusually large number of farmers sprayed their potatoes in 1903. Some were successful while others failed. Naturally, those who failed wish to know why they failed in order that they may be more successful another season. No doubt many are discouraged and have reached the conclusion that potato spraying is a failure.

There are two common causes of failure: (1) The spraying is not done at the proper time; or (2) it is not done thoroughly. During the past season the blight appeared so suddenly that many were taken unawares and, before they could spray, the plants had already become infected. Some made one or two applications in July when bugs were prevalent and then neglected further spraying until the blight appeared during the last week in August. In most cases where this was done there appeared to be but little benefit from the spraying.

An interesting example came under our own observation. Two small fields of potatoes on the Station farm were sprayed twice early in the season with bordeaux and paris green and then neglected until

the blight had made its appearance on a few leaves here and there all through both fields.

On September 1, alternate strips of six rows in both fields were very thoroughly sprayed with bordeaux mixture. As there was at that time fully nine-tenths of the foliage in perfect condition it was thought that the blight could surely be checked by spraying. However, such was not the case. By September 7 from two-thirds to three-fourths of all the leaflets on the sprayed plants were more or less affected and the unsprayed plants were but a trifle worse. A week later the difference was a little greater, but at no time was it of any importance. When the potatoes were dug it was found that in one field the yield of the sprayed and unsprayed rows was the same; namely, at the rate of 63 bushels per acre. While in the other field sprayed rows yielded 72 bushels per acre and the unsprayed 73. The area of each field was about two-thirds of an acre, about one-half being sprayed in each case. In this experiment spraying was a flat failure.

The explanation seems to be as follows: For a week preceding the date of spraying the weather had been exceptionally favorable to the spread of blight (*Phytophthora*). Spores from the affected leaves had been freely scattered over the healthy leaves, germinated and pushed their germ tubes into the tissues of the leaves. Thus at the time of spraying the fungus was already within the leaves out of reach of the fungicide but had not yet made sufficient growth to kill the tissue and cause the appearance of dead, brown spots. In spite of the spraying the fungus continued to spread within the leaves soon killing them. Had the spraying been made a week earlier it is likely that the results would have been much more satisfactory.

As a rule, it is unsafe to postpone spraying until the appearance of blight. Usually the blight becomes thoroughly established in a field before it is observed. In any case it is necessary to act very

promptly and there are likely to be unforeseen hindrances such as lack of materials or the sprayer being out of order. Then, too, it often happens, as in 1903, that the outbreak of blight occurs during a period of wet weather when it is almost impossible to get into the field to spray. The only sure way to avoid such difficulty is to commence early and spray regularly at intervals of ten to fourteen days as directed on page 161.

Sometimes, this method may result in slight loss. It appears that over the greater part of the State during the past season there was but little done, so far as the prevention of blight is concerned, by any spraying made before Aug. 1.[18] The important sprayings were those made during the last two weeks in August. However, one or two, and sometimes three, applications of poison for "bugs" must be made anyway and the extra expense of applying bordeaux with the poison is but a trifle which is generally more than repaid by the increased efficiency of the poison for "bugs," partial protection against flea-beetle injury, protection against early blight and paris green injury and by stimulation of the plants. Spraying often results in a marked increase in yield in seasons when there is no late blight.

When late blight is prevalent the spraying should be done very thoroughly. During damp, muggy weather in August there is little danger in over-doing spraying. Many fail because they are too saving of time and materials at such times.

Besides the two common causes of failure already mentioned there is another which sometimes leads farmers to believe that spraying does not prevent blight. We refer to the stem blight, an obscure disease found on Long Island and in the lower Hudson Valley.[19] The leaves of affected plants roll inward and upward exposing the under surface. Soon after, the whole plant begins to dry up slowly and finally dies prematurely. The stem is discolored at the surface

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[18] This does not apply to Long Island.

[19] For a more complete account of stem blight see Bulletin 101 of this Station, pp. 83–84.

of the soil and the tubers show brown streaks in the flesh at the stem end but do not rot. Stem blight is not prevented by spraying. The cause is unknown.

Failure to get results in potato spraying is sometimes attributed to the alleged imperfection of bordeaux mixture as a fungicide. Occasionally such erroneous views get in print.[20] To be sure, an easier and more effective method of preventing the ravages of potato blight is to be desired, but the urgent need at the present time is not for a better fungicide. The real need is that farmers shall learn to use bordeaux mixture properly.[21] For spraying potatoes, at least, bordeaux mixture is all right and it *is* a practical remedy for the

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[20] Curtis, F. C. Give us a better fungicide. *Rural New Yorker* **62:** 775. Oct. 31, 1903. This article was ably answered on page 818 of a later issue of the same paper.

[21] Notwithstanding all that has been said and written about the preparation and use of bordeaux mixture there is still extant a vast amount of ignorance concerning it. The truth of this is shown by the following letter received at the Station during the past season:—

——————, N. Y., June 29, 1903.

"W. H. Jordan,

"Geneva, N. Y.:

"Dear Sir:—If all farmers have the same trouble with bordeaux mixture I have I don't blame them for being reluctant about its use.

"Last Friday I had the nicest potatoes in my garden of any I have seen. Today they look as though I had sprinkled them with a pail of water and a pound of paris green.

"Friday morning I sprinkled them with a flower sprinkler, as a sprayer was not at hand, with bordeaux mixture which I have made as follows: In an old milk can I placed 15 gallons of water. In a cloth flour sack I placed 4 lbs. of quick lime and then put 6 lbs. of blue vitriol on top of that. Then I placed the sack in the water and left it about a week, shaking and stirring when I came near it. The solution looks like the ink I am writing with or soot water.

"For every quart of solution I used two quarts of water when I sprinkled. The vines seem to be burnt as if I had used an over-dose of paris green.

"Any information as to where I made a mistake will be sincerely received.

"Very respectfully yours,

"——— ———."

The only comment we care to make is, that people who will not follow directions have only themselves to blame if they get into trouble.

average farmer. This is shown by the results of the business experiments recorded in this bulletin and also by the experience of thousands of practical farmers scattered over those portions of the United States in which late blight is destructive.

Much of the agitation for a better fungicide than bordeaux mixture for spraying potatoes comes from people who have some substitute for it to sell. We wish here to state that while there are upon the market several patented fungicides or insecticides and fungicides combined which are recommended for use on potatoes, none of them, so far as we know, is equal to the ordinary, home-made bordeaux mixture and paris green as a preventive of blight and insect attacks.

CONDITION OF THE POTATO CROP IN NEW YORK IN 1903.

The severe spring drought, ending about June 7, delayed planting and made the crop unusually late. In many cases the potatoes did not come up well. However, a subsequent abundance of rain and cool weather soon put the crop in good condition. Except on Long Island there was little trouble from flea-beetles; and "bugs," too, were rather less troublesome than usual. Early blight (*Alternaria solani*) did no damage anywhere in the State.

On Long Island the late blight (*Phytophthora infestans*) seems to have first come to notice about July 10 to 15 and continued active during the remainder of the season, being most virulent about August 7 to 15. In the eastern part of Long Island, particularly, most fields were nearly done growing before the epidemic of August 7 to 15 and consequently the yield was not greatly shortened by the premature death of the plants. Some farmers who dug and marketed their crop before August 15 got good yields and lost but little from rot. During the following week rot set in to such an extent that most buyers refused to take any potatoes for several days. Thus, on the later part of the crop there was much loss from rot, variously estimated at from 5 to 75 per ct. in different fields.

Throughout the State late blight was general. Only a few localities escaped its ravages. In most places it was exceedingly virulent, being most destructive to the later planted potatoes. There was some of the disease among early potatoes, but not so much as in 1902. Up to about August 24 there was but little if any damage done to the late potatoes and the prospect for a fair crop was good. Then there came a period of rainy weather and late blight suddenly became exceedingly virulent. Early planted fields were attacked first, but in the end the late planted ones suffered the worst. All through the central and western portions of the State potato fields which should have remained green until October 1 were entirely dead by September 10 or earlier. In many cases the blight was followed by rot which caused still further loss.

After making a thorough survey of the situation the writers estimate that the loss from late blight (*Phytophthora infestans*) in New York State in the season of 1903 was fifty bushels per acre on an average. Since the area devoted to potatoes in the State is about 396,000 acres[22] and the average price at the digging time was 50 cents per bushel, the total loss sustained by our farmers is almost $10,000,000. A large part of this loss might have been prevented by spraying.

THE NATURE OF POTATO BLIGHT.

Farmers use the word blight to indicate almost any injury which causes potato foliage to turn brown and die. Hence, blight may be early blight, stem blight, late blight, flea-beetle injury, paris-green injury, the effects of drought, etc. Lack of space prevents a full discussion of the various forms of blight at the present time. However, a few words on the nature of late blight seem absolutely necessary to a proper understanding of the subject of potato spraying.

It is late blight which is chiefly responsible for the heavy losses on the potato crop in New York during the past two years. Late blight

[22] 395,640 acres in 1899, according to U. S. census.

appears during damp, muggy weather in August and September. It first appears on the leaves (usually the lower ones) in the form of small brown spots which rapidly enlarge. In moist weather the margins of the diseased spots are covered, on the under surface, with a fine, frost-like mildew (Plate XVII). In dry weather, this mildew may be difficult to detect. In the later stages of the disease affected plants frequently have the appearance shown in Plate XVI. Under favorable weather conditions a field of potatoes may be almost completely ruined within a few days after the first appearance of the disease.

Contrary to popular opinion, this form of blight is not caused by wet weather. The real cause is a parasitic fungus. Without the fungus there could be no blight of this kind, no matter what the weather conditions might be. Blight is most virulent in wet weather because the blight fungus thrive best and spreads most rapidly in wet weather.

In Plate XVIII the potato blight fungus, *Phytophthora infestans,* is illustrated. Figure 1 is a cross section of a blighted potato leaf. The branching, tree-like affairs hanging down from the undersurface are the spore-stalks of the fungus. It is these which make up the frosty mildew on the undersurface of affected spots. The egg shaped bodies at the ends of the branches are the spores. When one of these spores falls upon a healthy potato leaf in a drop of water it germinates within a few hours (after the manner shown in Fig. 5) and forces a slender, colorless tube into the tissue of the leaf. Once within the leaf the colorless tube branches and penetrates the leaf in all directions (See Fig. 1), absorbing nourishment from the cells of the leaf and later killing them. As the leaf tissues dies the fungus forms spore-stalks bearing new spores and the life cycle is complete. Usually about four or five days elapse between the germination of the spore and the production of a new crop of spores.

The rot of the tubers which frequently follows an attack of blight

is caused by spores which fall upon the ground and are washed down to the tubers by the rain. In some cases the fungus may pass down the stem and the tubers become infected in that way; but this method is the exception rather than the rule.

So far as known, the potato blight fungus has no spores which live over winter. It is believed that the fungus survives the winter in slightly affected tubers. Hence it is advisable to avoid planting tubers which show any signs of disease.

The philosophy of spraying as a preventive of blight and rot in potatoes is this:—The leaves are coated with a substance (bordeaux mixture) which either prevents the germination of the spores or else kills their delicate germ tubes before they can penetrate the leaf tissue. Consequently, the fungus is unable to establish itself in the leaves and there are no spores to fall upon the ground and cause rot.

CONCERNING THE USE OF POISON WITH BORDEAUX MIXTURE IN SPRAYING POTATOES.

In Bulletin 221 the writers advised against the use of paris green alone for "bugs," and recommended the use of bordeaux mixture containing paris green whenever it is necessary to fight insects. The experience of the past season tends to confirm us in this opinion. The extra expense of using bordeaux with the poison is slight and the benefits are likely to be considerable. (See Bulletin 221, pages 261–262.) In the Fleet experiment (Page 150) the expense of applying "Green Arsenoid" with a Leggett powder gun was 49 cents per acre for each application, while in the Jagger experiment (Page 134) the expense of applying bordeaux and paris green was only 98 cents per acre for each application. About the same quantity of poison per acre (two pounds) was used in both cases and the "Green Arsenoid" cost 4½ cents per pound less than the paris green. Hence, the actual extra expense of using the bordeaux was only 40

cents per acre. When the poison is applied with a sprayer the difference is merely the cost of the copper sulphate and a little extra labor in preparing the bordeaux.

Our recommendation to use paris green with bordeaux at the rate of one-half to three-fourth of a pound to 50 gallons of bordeaux has been criticised by some farmers who say the quantity of poison is too small. They cannot kill the "bugs." At the Station we have had no difficulty in controlling "bugs" with the amount of paris green named, but our success is due to two things:

(1) The application of bordeaux and poison has been made promptly upon the appearance of the "bugs." This is important, bacause a young "bug" is much more easily poisoned than the full grown beetle. The younger the "bugs" the more easily they are poisoned.

(2) At the Station spraying is usually done very thoroughly, using 100 gallons or more per acre; while farmers mostly use 25 to 50 gallons per acre. In using 100 gallons per acre the paris green would be applied at the rate of one pound per acre; while farmers using the same formula, and applying 25 gallons per acre would make a pound of paris green cover *four* acres. That is the difficulty. The important point to decide is not how much poison to use with 50 gallons of bordeaux, but, rather, how much poison to apply per acre. Accordingly, the directions for the use of poison have been changed (See page 161).

In this connection it may be mentioned that we think very highly of white arsenic as a poison for "bugs" provided it is used with bordeaux. Its chief advantage is its cheapness. A pound of white arsenic is equal to about two pounds of paris green in poisoning properties and costs only about one-third as much. Hence, it is about one-sixth as expensive as paris green.

It is prepared for use as follows:—Dissolve one pound of white arsenic and four pounds of salsoda (washing soda) in one gallon of

water by boiling 15 or 20 minutes. This makes the stock solution which can be bottled and kept until desired for use. For spraying potatoes add two quarts of the stock solution (one-half pound white arsenic) to the quantity of bordeaux required to cover an acre. This is equivalent to an application of one pound of paris green per acre.

In using the white arsenic stock solution with bordeaux mixture prepared by the potassium ferrocyanide test it is always advisable to add lime a little in excess of the amount required to satisfy the test in order to prevent the possibility of injuring the foliage. In our experience it has not injured the foliage in the least when used with bordeaux. If used in lime water there must be plenty of lime or the foliage will be injured. White arsenic was used with entire satisfaction in both of the Salisbury experiments at Phelps and in the Station experiments at Geneva and Riverhead.

DIRECTIONS FOR SPRAYING.

In general commence spraying when the plants are six to eight inches high and repeat the treatment at intervals of 10 to 14 days in order to keep the plants well covered with bordeaux throughout the season. During epidemics of blight it may be necessary to spray as often as once a week. Usually six applications will be required. The bordeaux should contain six pounds of copper sulphate to each 50 gallons. Whenever "bugs" or flea-beetles are plentiful add one pound of paris green or two quarts of white arsenic stock solution (See p. 160) to the quantity of bordeaux required to spray an acre.

Thoroughness of application is to be desired at all times, but is especially important when flea-beetles are numerous or the weather favorable to blight. Using the same quantity of bordeaux, frequent light applications are likely to be more effective than heavier applications made at long intervals; e. g., when a horse sprayer having but a single nozzle per row is used, it is better to go over the plants once a week than to make a double spraying once in two weeks.

Those who wish to get along with three sprayings should postpone the first one until there is danger of injury from "bugs" or flea-beetles, and then spray thoroughly with bordeaux and poison. The other two sprayings should likewise be thorough and applied at such times as to keep the foliage protected as much as possible during the remainder of the season. Very satisfactory results can be obtained from three thorough sprayings.

A single spraying is better than none and will usually be profitable, but more are better. It is unsafe to postpone spraying until blight appears. Except, perhaps, on small areas, it does not pay to apply poison alone for "bugs." When it is necessary to fight insects use bordeaux mixture and paris green together.

REPORT

OF THE

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IV. Conditions affecting chemical changes in cheese-ripening.

V. The status of phosphorus in certain food materials and animal by-products.

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REPORT OF THE CHEMICAL DEPARTMENT.

THE RELATION OF CARBON DIOXIDE TO PROTEOLYSIS IN THE RIPENING OF CHEDDAR CHEESE.*

L. L. VAN SLYKE AND E. B. HART.

SUMMARY.

1. The object of the work described in this bulletin was to ascertain the extent to which carbon dioxide is formed in American cheddar cheese during long periods of time in the process of ripening, and also to learn the nature of the chemical changes that give rise to the production of this gas.

2. Two cheeses were used for this study. One was entirely normal; the other was made from milk containing chloroform and kept under antiseptic conditions. The investigation was continued 32 weeks, when a chemical study was made of the proteolytic end-products.

3. In the normal cheese, carbon dioxide was given off continuously, though in decreasing quantities after about 20 weeks, and had not ceased at the end of 32 weeks. The total amount thus produced was 15.099 grams, equal to 0.5 per ct. of the fresh cheese. In the chloroformed cheese, the total amount of carbon dioxide produced was 0.205 gram, practically none being found after three weeks.

4. In the normal cheese, the following end-products of proteolysis

*Reprint of Bulletin No. 231.

were found: Tyrosine, oxyphenylethylamine, arginine in traces, histidine, lysine, guanidine, putrescine in traces, and ammonia. In the chloroformed cheese were found the same compounds, except oxyphenylethylamine, guanidine, putrescine, and ammonia; but arginine was found in marked quantities for the first time in cheese.

5. A consideration of the possible sources of carbon dioxide in the two cheeses indicates that, in the case of the chloroformed cheese, the carbon dioxide came from that present originally in the milk and that formed in the milk from the decomposition of milk-sugar before treatment with chloroform. In the case of the normal cheese, the carbon dioxide given off in its early age came largely from the decomposition of milk-sugar by lactic acid organisms, while a small amount was probably due to the carbon dioxide present in the milk and to the respiration of living organisms present in the cheese. The carbon dioxide produced after the first few weeks came apparently from reactions taking place in some of the amido compounds, among which we were able to identify the change of tyrosine and arginine into derived products with simultaneous formation of carbon dioxide.

6. In the chloroformed cheese, the only active proteolytic agents were lactic acid, galactase and rennet-pepsin. Under the conditions of our experiment, these agents were able to form neither ammonia nor secondary amido compounds with production of carbon dioxide. The presence of chloroform could not account for this lack of action. These results suggest that, in the normal cheese, there must have been some agent at work not present in the chloroformed cheese and that this extra factor was of a biological character.

INTRODUCTION.

In 1880 Babcock[1] carried on some experiments in cheese-curing, in which he attempted to measure the amount of carbon dioxide formed by cheese in ripening; but his study of each cheese was limited to short periods of time and the source of the carbon dioxide formed was not ascertained by him. The investigation described in this bulletin was undertaken primarily to learn to what extent carbon dioxide is given off by American cheddar cheese during long periods of time in the process of ripening. It was hoped that by such study we should be able also to learn the sources of the carbon dioxide thus formed and add to our knowledge in regard to some of the deep-seated chemical changes occurring in the ripening of cheddar cheese.

As material for use in carrying on the investigation, we made two cheeses. One was normal in every respect; the other was made from milk containing chloroform and was kept under antiseptic conditions, thus enabling us to suppress factors of biological activity. The study was continued for 32 weeks, at the end of which time we completed the work by making a study of the end-products in each cheese, including, more particularly, diamido compounds and their secondary cleavage products and tyrosine.

EXPERIMENTAL PART.

PREPARATION OF CHEESE.

For each cheese we used about 20 kgs. (45 pounds) of milk that had been drawn from the cows' udders not more than three hours. One cheese was made in the usual manner, being normal in every respect. In making the other cheese, we added to the milk at the start 4 per ct. by volume of chloroform and then enough lactic acid to equal 0.2 per ct. of the milk by weight. The rest of the process of cheese-making was carried on in the usual way. In both cases salt was added at the rate of 1 part for 400 parts of milk used. The normal cheese weighed 6 pounds and 10 ounces (3000 grams); the cheese containing chloroform weighed 7 pounds and 1 ounce (3203 grams), owing to the retention of chloroform and more water.

[1] Cornell Univ. Exp. Sta. Report, pp. 9-27 (1879-80).

ARRANGEMENTS FOR COLLECTING GAS EVOLVED BY CHEESE.

On April 1, 1902, each cheese was placed by itself under a bell-jar, each bell-jar being connected with its own apparatus for the absorption of carbon dioxide. During the entire period of the investigation, the cheeses were kept at a temperature of 60° F. (15.5° C.) Through the bell-jars, made tight by mercury joints, were passed daily about 8 liters of air, previously purified by passage through several wash-bottles containing potassium hydroxide. The air from the bell-jar containing the normal cheese was passed through a drying-train of strong sulphuric acid and calcium chloride and then through two Liebig bulbs, in order to absorb any carbon dioxide present. A water-bottle holding 8½ liters was used as an aspirator. The aspirator was started each morning at about 8 o'clock and stopped at 5 p. m. Over night, a stop-cock, separating the bell-jar from the wash-bottles containing potassium hydroxide and used for washing the inflowing air, was closed to prevent backward diffusion and consequent loss of carbon dioxide. The bulbs were weighed daily in the early period of the experiment, but only weekly during the later period.

In the case of the cheese containing chloroform and kept in an atmosphere of chloroform, the air from the bell-jar was passed through sulphuric acid and then through silver nitrate solution, in order to absorb any hydrochloric acid formed by decomposition of chloroform; the air was then passed through three flasks containing decinormal solution of barium hydroxide, to absorb the carbon dioxide, and finally through a potassium hydroxide guard. The same precaution against backward diffusion was observed as in the case of the other cheese. Liebig absorption bulbs and direct weighing could not be employed, since the air coming from the bell-jar was constantly laden with vapor of chloroform. To replace the loss of chloroform caused by aspiration, fresh portions of chloroform were added from time to time through a separatory funnel passing through the top of the bell-jar. A small dish placed on the top of the cheese inside the bell-jar received the chloroform. Once a week the barium carbonate formed was filtered through a weighed Gooch crucible, washed with dilute ammonia, dried and weighed. From the

amount of barium carbonate thus found, the amount of carbon dioxide was calculated. On April 1 this cheese contained 12 per ct. of chloroform, and on Nov. 28th, at the close of the investigation, it contained 10.5 per ct.

The normal cheese, before being placed under the bell-jar, was completely covered on the outside by a mixture of vaseline and creosote, in order to prevent as far as possible the growth of any molds on the surface of the cheese. This was done at the suggestion of the Station bacteriologist, Mr. H. A. Harding. In a similar experiment, when no special precautions were used, Babcock[2] found it impossible to prevent the growth of molds on the surface of cheese contained in a moist atmosphere under a bell-jar. He calls attention to the fact that the growth of mold was responsible for the formation of large quantities of carbon dioxide. It was absolutely essential, therefore, that in our work we should eliminate this source of carbon dioxide, if we were to learn anything definite about other sources of carbon dioxide formation within the cheese.

PRODUCTION OF CARBON DIOXIDE IN NORMAL CHEESE.

On the first day, we found the normal cheese had given off 0.044 gram of carbon dioxide; on the second day, 0.0978 gram; on the third day, 0.118 gram; and on the fourth day, 0.139 gram. On the eleventh day, the maximum daily record up to that time was made, 0.146 gram.

During the first week, we found 0.735 gram of carbon dioxide. This amount gradually decreased until the fourth week, when the amount was 0.364 gram. At this time the bell-jar was opened and samples taken for chemical analysis. Before opening the bell-jar, the aspiration was quickened somewhat in order to reduce the carbon dioxide in the bell-jar to the lowest amount possible. From the fourth to the ninth week, the amount of carbon produced increased gradually, reaching 0.644 gram for the ninth week. At this time a small patch of blue mold, covering about a square inch of surface, was observed. This was scraped off and more creosote applied. At the end of the eleventh week, another small patch of blue mold was noticed

[2] Cornell Univ. Exp. Sta. Report, p. 21 (1879 80).

and the amount of carbon dioxide formed had again risen. Again, at the end of the thirteenth week, another small patch of mold was found and the amount of carbon dioxide produced during this week was equal to that found during the first week of the experiment, 0.735 gram, the maximum weekly yield during the investigation. The whole outer surface of the cheese was then treated anew with the mixture of vaseline and creosote and afterwards no further trouble was experienced from the presence of molds. It was very noticeable that the presence of mold was quickly revealed by a sudden and marked increase in the amount of carbon dioxide formed. From the end of the thirteenth week to the close of the investigation at the end of the thirty-second week, the amount of carbon dioxide gradually decreased, being only 0.224 gram during the last week.

During the entire period of 32 weeks, the total amount of carbon dioxide produced was 15.099 grams. This is equal to 0.5 per ct. of the fresh cheese and represents a loss of solids equal to one-half pound for 100 pounds of fresh cheese. Undoubtedly other gases or volatile compounds are formed in small quantities, as shown by the blackening of the sulphuric acid in the drying-train. We hope to make later a more detailed study of the other gases formed in cheese during the ripening process.

In the table following, we present the detailed results of our work week by week:

TABLE I. AMOUNT OF CARBON DIOXIDE FORMED IN NORMAL CHEDDAR CHEESE DURING EACH WEEK OF INVESTIGATION.

No. of week.	Grams of CO_2 formed.	No. of week.	Grams of CO_2 formed.	No. of week.	Grams of CO_2 formed.
1	0.735	12	0.406	23	0.462
2	0.672	13	0.735*	24	0.357
3	0.420	14	0.476	25	0.343
4	0.364	15	0.441	26	0.427
5	0.476	16	0.434	27	0.400
6	0.574	17	0.539	28	0.366
7	0.525	18	0.469	29	0.340
8	0.574	19	0.448	30	0.300
9	0.644*	20	0.497	31	0.260
10	0.539	21	0.539	32	0.224
11	0.651*	22	0.462		

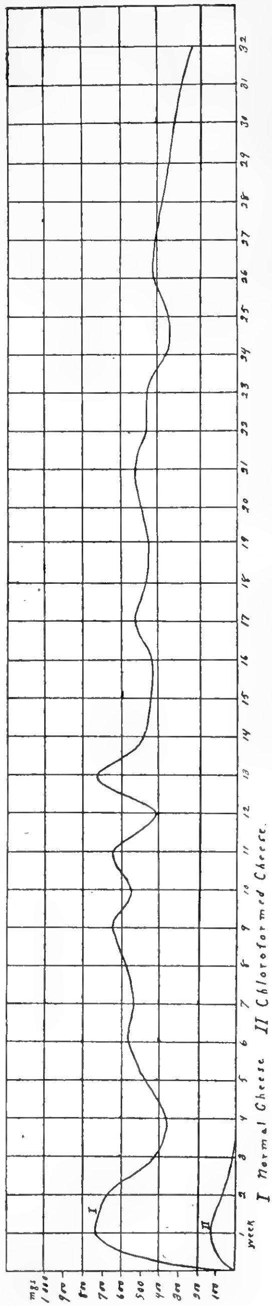
* Increase due to presence of small amount of mold.

PRODUCTION OF CARBON DIOXIDE IN CHEESE CONTAINING CHLOROFORM.

In the cheese containing chloroform, we planned to suppress all biological activity. In order to ascertain how completely we succeeded in this respect, Mr. John Nicholson, the assistant bacteriologist of the Station, made bacteriological examinations from time to time. His results showed that the cheese was practically sterile throughout the entire period of the investigation.

The quantity of carbon dioxide produced by this cheese amounted only to about 0.019 gram a day during the first week, after which it fell off rapidly, the amount during the third week being less than 0.003 gram a day. At the end of three weeks, carbon dioxide practically ceased to be formed. The total amount of carbon dioxide produced by this cheese was 0.205 gram, about three-fourths of which was given off during the first nine days.

In the accompanying diagram, we show in graphic form the amounts of carbon dioxide produced by the two cheeses during the period of investigation.



PROTEOLYTIC END-PRODUCTS IN THE NORMAL CHEESE.

At the end of 32 weeks, the normal cheese was taken from the bell-jar, the covering of vaseline and creosote removed, and also the entire outer rind of the cheese to the thickness of about one-half an inch. The remainder of the cheese was cut into small pieces and dried at 140° F. (60° C.) for several days. It was then broken into finer particles by

rubbing and again dried, after which it was extracted with ether to remove fat and then reduced to a finely powdered white mass. This mass was extracted with several portions of water at 122° F. (50° C.), until about 12 liters were collected, the water-soluble contents of the mass having been thoroughly extracted by this treatment. This extract was precipitated with tannin and filtered; the tannin in the filtrate was removed by lead acetate. The resulting precipitate of lead tannate was filtered and washed three times by suspension in water and refiltering. The excess of lead was removed by sulphuric acid and the last traces by hydrogen sulphide. The filtrate was then carefully concentrated at 55° C. to about 4 liters, made acid with 5 per ct. of sulphuric acid and precipitated with phosphotungstic acid. The precipitate was washed with dilute sulphuric acid. The filtrate from the phosphotungstic acid precipitate was examined for tyrosine and the precipitate for oxyphenylethylamine and the hexon bases.

Tyrosine.—The filtrate from the precipitate by phosphotungstic acid was treated with barium oxide to remove the phosphotungstic acid and the barium hydroxide in the filtrate carefully removed by sulphuric acid. This filtrate was concentrated to a small volume. On standing, crystals separated from the solution having much the appearance of tyrosine. These were filtered, redissolved in water, recrystallized several times from water after concentration of solution and finally washed with alcohol and dried over sulphuric acid *in vacuo*. A nitrogen determination by the Kjeldahl process gave the following results:

	Calculated for tyrosine. ($C_9H_{11}NO_3$)	Found.
N	7.68 per ct.	7.73 per ct.

The substance gave the color reactions that are characteristic of tyrosine and was undoubtedly tyrosine. The separation of other monoamido compounds was not attempted.

Oxyphenylethylamine.—About one-fourth of the phosphotungstic acid precipitate, obtained in the manner previously described, was decomposed by barium oxide and filtered. The excess of barium hydroxide was removed from the filtrate by means of carbon dioxide. The clear filtrate was concentrated at a low

temperature and then treated with benzoyl chloride in dilute alkaline solution according to the Schotten-Baumann method.[3] This method has been employed by Langstein[4] in the separation of oxyphenylethylamine formed by an intense peptic digestion of egg-albumin. An abundant precipitate separated, which was filtered and washed with cold water. It was then dissolved in hot alcohol and evaporated to small bulk. On standing, an abundant crop of crystals separated, which were filtered, washed with ether and dried over sulphuric acid *in vacuo*.

This product had a melting-point of 169° C. (uncorrected), agreeing exactly with the oxyphenylethylamine obtained by Langstein. The following results were obtained by determining the nitrogen by the Kjeldahl method and the carbon and hydrogen by combustion.

	Calculated for benzoylderivative of oxyphenylethylamine. $C_8H_9NO(C_6H_5CO)_2$	Found.
C	76.50	76.19
H	5.54	5.44
N	4.06	4.10

This product was undoubtedly oxyphenylethylamine formed, as we shall point out later, from tyrosine with the accompaniment of carbon dioxide as a by-product.

Hexon bases.—The remainder of the phosphotungstic acid precipitate, obtained in the manner previously described, was decomposed by barium oxide and the excess of barium hydroxide was removed by careful addition of sulphuric acid. The resulting filtrate was worked for the hexon bases according to the Kossel-Kutscher[5] method.

(1) *Arginine.*—After separating histidine from the solution, which should contain only arginine and histidine, a determination was made of the nitrogen in this solution containing only arginine. The amount of arginine, thus determined, equivalent to the nitrogen found, was only 0.364 gram, an amount too small to obtain in the form of crystals.

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[3] *Ber. d. chem. Ges.*, **17**: 2545 (1884) and **19**: 3218 (1886).

[4] *Beit. z. Chem. Physiol. und Pathol.*, **2**: 229 (1902).

[5] *Ztschr. physiol. Chem.*, **31**: 165 (1900).

(2) *Histidine.*—This substance was separated as the di-chloride, of which we obtained 0.850 gram. An analysis gave the following results:

	Calculated for histidine hydrochloride. ($C_6 H_9 N_3O_2$ 2HCl)	Found.
N	18.42	18.15
Cl	31.11	30.98

(3) *Lysine.*—We separated about 2 grams of lysine in the form of picrate, which gave the following results on analysis:

	Calculated for lysine picrate. ($C_6H_{14} N_2O_2 C_6H_3 N_3O_7$)	Found.
N	18.66	18.80
C	38.40	38.44
H	4.53	4.56

(4) *Guanidine.*—The mother-liquor from the lysine precipitate was extracted by a mixture of alcohol and ether and then treated with gold chloride in very dilute hydrochloric acid solution, following the method of Winterstein and Thöny.[6] On standing, a crystalline substance soon separated from the solution, behaving like a guanidine gold salt, yielding about 0.300 gram, which on analysis gave the following results:

	Calculated for guanidine gold chloride. (CH_5N_3 HCl $AuCl_3$)	Found.
Au	49.79	49.63

So small an amount of this substance was obtained that we were unable to make other determinations to establish its identity with greater certainty, but it is highly probable that the substance is guanidine.

(5) *Putrescine.*—We expected to separate the other cleavage product of arginine, putrescine. The lysine solution had a strong odor of putrescine and it was unquestionably present but we failed in our efforts to isolate this base. It appears probable that the cleavage of arginine had only progressed as far as the formation of guanidine and ornithine, and that the latter compound had been decomposed only to a small extent, forming

[6] *Ztschr. physiol. Chem.*, **36**: 28 (1902).

merely traces of putrescine. The fact that the cheese was of good flavor, except for a slight taste of creosote, indicates that putrescine could not have been present in considerable quantities.

PROTEOLYTIC END-PRODUCTS IN THE CHEESE CONTAINING CHLOROFORM.

The cheese containing chloroform was, at the end of 32 weeks, treated, preparatory to extraction, in the manner described above in the case of the normal cheese. It was extracted with several portions of water at 122° F. (50° C.) until about 12 liters of extract were obtained, the mass having been completely extracted by this treatment. The water extract was treated with tannin and filtered; the tannin was removed by lead acetate; the precipitate was filtered and well washed. The excess of lead was removed by sulphuric acid and the last traces by hydrogen sulphide. The filtrate was concentrated at a low temperature, never above 131° F. (55° C.), to a small volume. It was then precipitated by phosphotungstic acid, filtered and well washed with dilute sulphuric acid.

Tyrosine.—After removing the phosphotungstic acid by barium oxide and then the barium hydroxide by careful treatment with sulphuric acid, the solution was concentrated to a small volume and set aside for crystallization. After standing several days, there separated from the solution a mixed crystalline and gummy mass. This precipitate was filtered, dissolved in a small volume of water poured into cold 95 per ct. alcohol and allowed to stand several days. A crystalline precipitate formed at the bottom of the solution. The precipitate was filtered, redissolved in water, decolorized with charcoal and filtered. On concentration, this filtrate deposited a copious crystalline precipitate, greatly resembling tyrosine in appearance. These crystals were washed with ether and dried over sulphuric acid *in vacuo*. A determination gave 7.70 per ct. of nitrogen, as compared with 7.73 calculated for tyrosine.

We were unable to find in this cheese any trace of oxyphenylethylamine.

Hexon bases.—The phosphotungstic acid precipitate was decomposed by barium oxide, the barium hydroxide was removed from the filtrate by sulphuric acid and then arginine and histidine were precipitated by silver sulphate in barium hydrate solution in the usual way.

(1) *Arginine.*—After the separation of histidine from arginine, a determination of nitrogen in the remaining solution indicated the presence of about 1.5 grams of arginine, which is by far the largest amount we have ever succeeded in separating from any cheddar cheese with which we have worked. The solution was evaporated, dilute nitric acid added and then set aside for crystallization. After standing about a week, the solution had partly crystallized. These crystals were removed by filtration, washed with absolute alcohol and ether and dried over sulphuric acid *in vacuo.* Analysis gave the following result:

	Calculated for arginine nitrate. (C_6H_{14} N_4O_2 HNO_3 $\frac{1}{2}H_2O$)	Found.
N	28.45	28.32

To the mother-liquor was added silver nitrate with 2 or 3 drops of dilute nitric acid and the solution was allowed to evaporate *in vacuo.* Crystals soon separated and after a few days the entire mass was crystalline. The crystals were washed with alcohol and ether and dried over sulphuric acid *in vacuo.* A silver determination gave the following results:

	Calculated for arginine silver nitrate. (C_6 H_{14} N_4 O_2 $AgNo_3$ HNO_3)	Found.
Ag	26.54	26.49

We believe we are justified in regarding this substance beyond question as arginine. So far as we are able to learn, this is the first time arginine has been separated from a ripening cheese; and, in this case, we succeeded only when all biological factors had been eliminated.

(2) *Histidine.*—This base was separated as a di-chloride. Analysis gave the following results:

	Calculated for histidine hydrochloride. (C_6 H_9 N_3 O_2 $2HCl$)	Found.
Cl	31.11	31.08
N	18.42	18.59

(3) *Lysine.*—This substance was easily separated as picrate and analyzed as follows:

	Calculated for lysine picrate ($C_6 H_{14} N_2 O_2 C_6 H_3 N_3 O_7$)	Found.
N	18.66	18.78
H	4.53	4.38
C	38.40	38.51

We were unable to separate guanidine from the mother-liquor of the lysine precipitate and we believe that it was not present. We were unable, also to detect any of the other possible cleavage products of arginine. The solution containing lysine had no such odor as the corresponding solution obtained from the normal cheese and was, indeed, conspicuously free from the putrescine odor that was so characteristic of the lysine solutions obtained from normal cheese ripened at about 60° F. (15.5° C.)

ANALYSIS OF CHEESES.

At intervals determinations were made of the moisture, total nitrogen, water-soluble nitrogen and nitrogen in the form of unsaturated paracasin lactate, of amido compounds and of ammonia. The results are given in the subjoined table:

TABLE II.—RESULTS OF ANALYSIS OF CHEESES.

	Age when analyzed.	Moisture in cheese.	Nitrogen in cheese.	Nitrogen expressed as percentage of total nitrogen in cheese, in form of—			
				Water soluble nitrogen.	Amido compounds.	Ammonia.	Paracasein monolactate
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Normal cheese.	Fresh	36.53	3.54	6.78	2.52	0	58.47
	1 mo.	35.83	3.72	18.82	11 83	0.70	42.50
	3 "	34 84	3.92	25.50	17.86	1.78	33 42
	7 "	33 94	4.09	38.14	28.12	2.30	20 54
Cheese containing chloroform.	Fresh	46.23	2.45	9.80	3.67	0	35.92
	1 mo.	45.77	2.50	20.80	11.20	0	22.40
	3 "	44.38	2.51	27.90	14.74	0	17.93
	8 "	44.37	2.73	40.30	23.10	0	7.33

If we compare the two cheeses in question with reference to the data contained in the preceding table, we notice:

(1st) In respect to the water-soluble compounds of nitrogen, the two cheeses did not differ greatly, the slight difference being in the favor of the chloroformed cheese. Ordinarily we should expect the normal cheese to form soluble nitrogen compounds with somewhat greater rapidity than the cheese containing chloroform. Two conditions that were present furnish an explanation of these unexpected results. In the first place, some of the creosote used in coating the normal cheese diffused into the body of the cheese and exerted some antiseptic influence, retarding enzyme and bacterial activity and giving proteolytic results lower than we commonly find in case of normal cheese. In the second place, the chloroformed cheese contained about 10 per ct. more water than the normal cheese. We have in our unpublished records numerous data which establish the fact that increase of moisture in cheese very noticeably increases the amount of water-soluble nitrogen compounds formed in a given time. The difference in results of the last analyses was made more favorable to the chloroformed cheese, since it was a month older.

(2nd) After the first month, the amount of amido compounds formed in the normal cheese was greater than in the chloroformed cheese.

(3rd) In the normal cheese, ammonia was formed, though somewhat less in amount than under conditions entirely normal; while in the chloroformed cheese no trace of ammonia was formed.

(4th) We have previously[7] pointed out that the formation of water-soluble nitrogen compounds in cheese-ripening appears to take place at the expense of the paracasein monolactate (soluble in dilute solution of sodium chloride). The figures in the preceding table furnish confirmatory evidence of this, since the paracasein monolactate diminishes at the same time the water-soluble nitrogen increases.

[7] N. Y. Agr. Exp. Sta. Bull. No. 214, p. 60 (1902).

(5th) The amount of water-soluble proteolytic compounds formed in cheese can not safely be used as the sole basis of comparison in respect to the extent of chemical changes taking place in ripening cheese. In the two cheeses investigated, the amounts of water-soluble nitrogen did not greatly differ, but an examination of the end-products of proteolysis showed changes much more complete in the case of the cheese containing the smaller amount of water-soluble nitrogen. The true measure of cheese-ripening must be found in the character and amount of the individual products formed rather than in the total amount of water-soluble nitrogen.

GENERAL SUMMARY OF RESULTS.

We now bring together, in a form allowing ready comparison, the results that have been presented in detail in the foregoing pages.

In Normal Cheese.	*In Cheese Containing Chloroform.*
(1) Production of carbon dioxide.	(1) Production of carbon dioxide.
(a) Total in 32 weeks, 15.099 grams.	(a) Total, 0.205 gram.
(b) Weekly variation from 0.735 gram in first, to 0.224 gram in last, week.	(b) Ceased entirely after three weeks.
(2) Proteolytic end-products formed.	(2) Proteolytic end-products formed.
(a) Tyrosine in small amounts.	(a) Tyrosine.
(b) Oxyphenylethylamine.	(b) No oxyphenylethylamine.
(c) Arginine in traces.	(c) Arginine in marked quantity.
(d) Histidine.	(d) Histidine.
(e) Lysine.	(e) Lysine.
(f) Guanidine.	(f) No guanidine.

(g) Traces of putrescine.	(g) No putrescine.
(3) Analysis of cheese.	(3) Analysis of cheese.
(a) Ammonia formed.	(a) No ammonia formed.
(b) Amido compounds more abundant.	(b) Amido compounds less abundant.

DISCUSSION OF RESULTS.

We have seen above that results varying in a most marked manner were obtained from the two cheeses used in our investigation. We will now consider some of these differences with a view to finding some satisfactory explanation of the facts presented.

THE SOURCES OF CARBON DIOXIDE IN CHEESE.

What was the source of the carbon dioxide produced in each cheese? Why did the normal cheese produce relatively so large quantities of carbon dioxide over so long a period of time and why did the chloroformed cheese produce so small quantities and for so brief a period?

As possible sources of carbon dioxide in cheese, we have (1) the milk used in making cheese, (2) the decomposition of milk-sugar in the formation of lactic acid, (3) the respiration of living cells present in the cheese and (4) the chemical decomposition of compounds present in the cheese. We will consider these separately.

(1) *Milk as a source of carbon dioxide in cheese.*—According to Marshall,[8] fresh milk, before exposure to air, contains on an average about 4 per ct. of free carbon dioxide by volume and this is reduced one-half by aeration. In the amount of milk used by us in making each cheese, we should have about 0.800 gram of carbon dioxide. Some of this is of necessity lost in the process of cheese-making, but we could expect to retain in the cheese 0.200 to 0.300 gram of the carbon dioxide originally present in the milk.

(2) *The decomposition of milk-sugar as a source of carbon dioxide in cheese.*—E. Kayser[9] has shown that certain lactic acid bacteria produce, as the result of their action on milk-sugar, not

[8] Special Bull. No. 16, Mich. State Agr. Coll. Exp. Sta. (1902).

[9] *Ann. Past.*, **8**: 779 (1894).

only lactic acid but also certain by-products, among which is carbon dioxide. The milk-sugar is undergoing decomposition all through the normal process of cheese-making, and the carbon dioxide thus formed becomes incorporated in the cheese-curd to some extent. In our normal cheese, the milk-sugar actually present before the cheese was placed under the bell-jar amounted to 0.3 per ct. of the cheese. This was changed into lactic acid with the accompanying formation of carbon dioxide in the early period of ripening and the carbon dioxide thus formed, together with that occluded in the cheese mass, can readily account for the relatively large amount of carbon dioxide found during the first week in the normal cheese. In the case of the chloroformed cheese, a certain amount of the milk-sugar had undergone fermentation before chloroform was added, as shown by a determination of the sugar in the curd the day after the cheese was made. The amount found was low compared with the amount present in perfectly fresh curd. Such fermentation would produce small amounts of carbon dioxide, which would be absorbed by the milk and pass into the cheese mass. Carbon dioxide thus enclosed in a cheese would again be given out into an atmosphere such as was present in the bell-jar, that is, one free from carbon dioxide.

(3) *Respiration of living cells present in cheese as a source of carbon dioxide.*—It is well known that living cells give off carbon dioxide as the result of respiration processes. It is also known that in a fresh normal cheese of the cheddar type the number of micro-organisms, generally lactic acid formers, increases rapidly for about 10 days and then after about 25 days falls very rapidly for a period of 10 days to a relatively small number, as shown by Russell and Weinzirl.[10] In any case, we can not look to the respiration processes of living cells in cheese as the source of the carbon dioxide formed after the first few weeks. As regards this possible source of carbon dioxide during the early age of a cheese, when the micro-organisms are present in enormous numbers, we should be justified in expecting that at this time the amount of carbon dioxide produced would be very

[10] Ninteenth Ann. Rept. Wis. Exp. Sta., p. 95 (1896).

much greater than that formed later, when the lactic acid organisms have largely disappeared, if their respiration is the source of any appreciable amount of carbon dioxide. The results secured by us with our normal cheese do not show that there was any such comparatively large amount of carbon dioxide produced at the time the lactic acid organisms were most abundant. The somewhat larger amount of carbon dioxide produced during the first two weeks is undoubtedly due mostly to the decomposition of milk-sugar and not to the respiration process of the living cells present in the cheese. In the case of our chloroformed cheese, we inhibited the activity of living organisms and this source of carbon dioxide did not therefore exist in the cheese.

(4) *Chemical decomposition of compounds present in the cheese.*—Emerson[11] has lately shown that tyrosine, through the action of the enzymes of the pancreas, can be converted into oxyphenylethylamine with simultaneous cleavage of carbon dioxide, in accordance with the following representation of the reaction:

$$\begin{gathered} HO\ C_6H_4\ \ CH_2\ \ CH(NH_2)\ COOH = \\ HO\ \ C_6H_4\ \ CH_2\ \ CH_2\ (NH_2)+CO_2 \end{gathered}$$

Langstein[12] has also shown the same reaction in the case of a long-continued peptic digestion of the coagulated portion of the blood-serum of a horse.

Ellinger[13] has shown the formation of putrescine from ornithine and of cadaverine from lysine, with the splitting off of carbon dioxide, by the action of bacterial ferments. The following equations represent these reactions:

$$\begin{gathered} CH_2(NH_2)\ \ CH_2\ \ CH_2\ \ CH(NH_2)COOH = \\ CH_2(NH_2)\ \ CH_2\ \ CH_2\ \ CH_2(NH_2)+CO_2. \\ CH_2(NH_2)\ \ (CH_2)_3\ \ CH(NH_2)\ \ COOH = \\ CH_2(NH_2)\ \ (CH_2)_3\ \ CH_2(NH_2)+CO_2. \end{gathered}$$

Lawrow[14] found the same reaction taking place in an intense peptic auto-digestion of the stomach.

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[11] *Beit. z. chem. Physiol. und Pathol.*, **1**: 501 (1902).

[12] Ibid. 507

[13] *Ber. d. chem. Ges.*, **31**: 3183 (1898).

[14] *Ztschr. Physiol. Chem.*, **33**: 312 (1901).

The work of Nencki and of Spiro[15] has shown that phenylethylamine can be formed from phenylalanine with separation of carbon dioxide.

Of these different reactions furnishing carbon dioxide, we find in the normal cheese under investigation evidence that tyrosine has changed into oxyphenyethylamine and that the decomposition of arginine has resulted in the formation of its simpler products. We cannot say whether Nencki's reaction occurred, by which phenylalanine was changed into phenylethylamine, since we did not examine the cheese for these compounds. It is easily conceivable that such a change may take place, since E. Fischer[16] has shown the presence of phenylalanine among the cleavage products of casein. There probably await discovery other similar reactions, now unknown, bearing on the formation of carbon dioxide in proteolytic changes.

It appears to us that the carbon dioxide formed after the first few weeks of ripening, in the case of the normal cheese, must have come very largely from the decomposition of such compounds as tyrosine and arginine. In the case of the different normal cheddar cheeses that we have previously investigated, the arginine and tyrosine commence to undergo proteolytic change quite early in the ripening process.

Reviewing briefly our discussion about the sources of carbon dioxide in cheese, we believe, from the evidence furnished, that the carbon dioxide given off in the early age of the normal cheese came largely from the decomposition of milk-sugar by lactic acid organisms, while a small amount was probably due to the carbon dioxide present in the milk and to the respiration of living organisms present in the cheese. The carbon dioxide produced after the first few weeks could apparently come only from the decomposition of some compounds present in the cheese, among which we were able to identify the change of tyrosine and arginine into derived products with simultaneous formation of carbon dioxide.

In the case of the chloroformed cheese, none of the carbon dioxide could have come from the respiration of living cells or

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15 *Beit. z. chem. Physiol. und Pathol.*, **1**: 347 (1901).

16 *Ztsch. Physiol. Chem.*, **33**: 151 (1901).

the decomposition of compounds like arginine and tyrosine. The amount of carbon dioxide originally present in the milk combined with that formed in the milk from the decomposition of milk-sugar before treatment with chloroform was sufficient to furnish the small amount that was given off by this cheese.

CAUSE OF DIFFERENCE IN BEHAVIOR OF NORMAL CHEESE AND CHLOROFORMED CHEESE.

We have seen that, in the chloroformed cheese, only an insignificant amount of carbon dioxide was present and after 3 weeks practically none was found. In the normal cheese, carbon dioxide was found in relatively large quantities and, even at the end of 32 weeks, more carbon dioxide was being formed in one week than the total amount produced in the other cheese. Why should there have been so marked a difference?

The answer to this question involves a consideration of the causes that produce the proteolytic changes observed in the normal cheese-ripening process. The agencies sharing in this work are the following, so far as our present knowledge goes: (1) Some acid, (2) enzymes present in the milk before it is made into cheese, chief of which is galactase, (3) pepsin and pseudopepsin, added with the rennet in the process of cheese-making and (4) micro-organisms, chiefly bacteria.

In the case of our chloroformed cheese, we had present of these different agencies, acid, galactase and rennet-pepsin. These agencies, under the conditions of our experiment, were unable to split carbon dioxide from tyrosine with the formation of oxyphenylethylamine or change arginine into those of its products that we have commonly found in cheese ripening normally. As previously stated, this is the first instance in our knowledge in which arginine has been found in ripening cheese and we were able to find it only because we had inhibited the action of living organisms. These facts suggest strongly that the active cause in our normal cheese that was responsible for the deep-seated proteolysis, accompanied by production of carbon dioxide, was a biological factor.

It may be thought that our results fail to agree with those of Lawrow, cited above, in which he succeeded by an auto-digestion of a stomach in obtaining putrescine and cadaverine, probably with formation of carbon dioxide. It must be kept in mind, however, that in his work the conditions were favorable to a much more intense reaction, because he not only had a highly concentrated pepsin solution but he also kept the acid content of his digesting solution high, conditions that are not present in cheddar cheese.

It may be thought, again, that the activity of the enzymes, galactase and rennet-pepsin, in our one cheese was checked by the chloroform and that we should, under the circumstances, expect just the results we obtained. In Bulletin No. 203 of this Station, we have furnished evidence showing that chloroform does not inhibit the activity of galactase; and we shall later publish results, secured in co-operation with the bacteriological department, confirming our previous work. Lawrow's work showed that chloroform did not inhibit the activity of a concentrated pepsin solution. In view of the evidence at hand, it appears to us quite improbable that, if chloroform has any inhibiting influence on galactase and rennet-pepsin, we should find these two enzymes, under the conditions of the experiment, able to furnish such end-products as arginine, lysine and tyrosine, but unable to produce compounds resulting from further proteolysis such as putrescine, guanidine and ammonia. If chloroform interfered with the work of these enzymes, we should expect either that there would be no proteolysis or that we should find the same compounds that are formed in the absence of chloroform but in much smaller quantities. As a matter of fact, we find these enzymes quite as active in the chloroformed cheese as in the normal cheese in forming certain compounds but they stop short in their work, appearing unable to produce the further cleavage that results in the production of carbon dioxide. This failure to furnish products beyond a certain point seems to us to depend upon other conditions than the presence of chloroform.

The only logical conclusion suggested by the results of our work appears to us to be that the enzymes, galactase and pepsin are able to furnish such end-products as arginine, lysine and

tyrosine under the conditions existing in cheddar cheese but are not able to split these compounds into simpler ones with simultaneous formation of carbon dioxide. If this is true, then we must look to some other source as the active agency in decomposing primary into secondary proteolytic cleavage products with production of carbon dioxide. The only cause that can be suggested is a biological factor. Several investigators have made a study of the gases in cheese, especially in connection with the formation of holes in emmenthaler cheese and the so-called "huffing" common to hard cheeses; and they have without exception attributed the formation of gases to micro-organisms. Thus, Baumann[17] found the gas in cheese examined by him to consist of 63 per ct. of carbon dioxide. In this particular case he assigned *Bacillus diatrypticus casei* as the cause. Later von Klecki[18] in a similar investigation found gas produced in an inoculated milk containing 31.76 per ct. of carbon dioxide and he attributed its formation to *Bacillus saccharobutyricus*. Adametz, Freudenreich and Weigmann have assigned other organisms. Jensen[19] suggests that the gas that causes holes in cheese is mostly carbon dioxide and that this comes from the action of lactic acid bacteria upon the nitrogen compounds of the cheese. While no one has probably yet solved the problem as to what specific organism or organisms are responsible for the deep seated chemical changes occurring in cheese, the general tendency has been to look to some biological source as a prominent factor in cheese-ripening.

From the consideration of quite different data, we have previously[20] arrived at the conclusion that there is a biological factor at work in normal cheese-ripening. In the results presented in this paper and also in the case of a large number of results not yet published, we always find that in a chloroformed cheese, where galactase and rennet-pepsin are the only proteolytic agents present, we never have ammonia formed, while we always find

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[17] *Landw. Versuchsta.*, **42**: 181 (1892).

[18] *Centr. Bl. f. Bakteriol. u. Parasitenk*, II Abt., **2**: 21 (1896).

[19] *Centr. Bl. f. Bakteriol. u. Parasitenk.*, II Abt., **4**: 217 (1898).

[20] N. Y. Agr. Exp. Sta. Bul. No. 203, p 244 (1901).

it early in normal cheese. In these cases, the only difference appears to be the presence or absence of a biological agent.

What specific organism or combination of organisms may constitute this biological factor in cheese-ripening, we are not now able to say. In co-operation with the bacteriological department of this Station, we have work in progress by which we hope definitely to establish whether these deep-seated chemical changes in cheese-ripening, which can not be attributed to galactase or rennet-pepsin, are due to lactic acid organisms or to liquefying bacteria and their enzymes or to some combination of these.

RENNET-ENZYME AS A FACTOR IN CHEESE-RIPENING.*

L. L. VAN SLYKE, H. A. HARDING AND E. B. HART.

SUMMARY.

I. The object of the work described in this bulletin was to ascertain to what extent the formation of soluble nitrogen compounds in cheese-ripening is due to the rennet-extract used in cheese-making. In the case of the work previously done here and elsewhere, the effect of rennet-enzyme has not been studied apart from the action of other factors that are present in cheese-ripening. It was our purpose to study its action by itself, apart from other proteolytic agents.

II. The action of rennet-extract was first studied in cheese containing rennet-enzyme as the only proteolytic factor, with and without acid, and also with and without salt. In these experiments (44 to 51), all milk-enzymes were destroyed by heating the milk at 95°C. to 98°C. (203°F. to 208°F.), the coagulable property of the milk-casein was restored by the addition of either calcium chloride or carbon dioxide gas, and all organisms were rendered inactive by chloroform. Acid, when present, was furnished by addition of pure lactic acid.

III. The action of fresh rennet-extract on casein in milk, with and without acid, was studied in comparison with old rennet-extract, and also in comparison with commercial pepsin. In these experiments, the milk-enzymes were destroyed by heat and all organisms were rendered inactive by chloroform.

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IV. The action of rennet-extract in cheese was studied in comparison with commercial pepsin. In these experiments (55 to 57), the milk-enzymes were destroyed by heat and commercial pepsin was added in different amounts. No chloroform was used and there were present, therefore, such organisms as were introduced during the process of making cheese. Acid was furnished by addition of hydrochloric acid.

V. The action of rennet-extract on paracasein dilactate was studied in comparison with commercial pepsin. In these experiments, rennet-enzyme and commercial pepsin, sterilized by formaldehyde, were allowed to act upon sterile paracasein dilactate.

VI. The action of rennet-extract was studied in cheese containing acid-forming and some proteolytic organisms. In these experiments (52 and 53), the milk-enzymes were destroyed by heat, acid was furnished by a lactic-acid "starter," but no chloroform was used. We thus had as our only proteolytic agents rennet-enzyme in the presence of acid and such organisms as were introduced in the "starter" or that got into the milk or curd during the operation of cheese-making.

VII. Special work was done to show that all milk-enzymes were destroyed by heat. Bacteriological examinations were made of the cheese and milk.

VIII. In the case of every experiment made, there was little or no digesting action by either rennet-enzyme or commercial pepsin in the absence of acid, while the action was marked in the presence of acid.

IX. In the absence of acid in cheese, no paracasein lactate is found and little or no proteolysis occurs; in the presence of acid in the cheese, paracasein monolactate is formed and digestion takes place, the rennet-ferment being the active agent. The ability of rennet-enzyme to convert paracasein into soluble nitrogen compounds ap-

pears to depend upon the presence of acid, resulting in the formation of paracasein monolactate.

X. Rennet-enzyme and commercial pepsin act essentially alike in forming soluble nitrogen compounds, when compared with each other in the case of cheese, milk and paracasein dilactate.

XI. In the case of both rennet-enzyme and commercial pepsin, the chemical work performed by the ferments is confined mainly to the formation of the paranuclein, caseoses and peptones, while only small amounts of amides are formed, and no ammonia.

XII. Rennet-enzyme is really a peptic ferment.

XIII. Salt, in the proportions found in normal cheese, appears to have little effect upon the action of rennet-enzyme in cheese-ripening. The experiments on this point are, however, not regarded as conclusive.

XIV. The abnormal conditions present in many of the experiments, such as pasteurized milk, calcium chloride and chloroform, would tend, if they had any effect at all, to decrease the digestive action of rennet-enzyme. Our results, therefore, may properly be regarded as representing the minimum effect of rennet-enzyme in cheese-ripening.

XV. The digestive action of rennet-enzyme does not appear to extend to the formation of compounds that produce the flavor of cheese.

INTRODUCTION.

In Bulletin No. 203 of this Station, we published the results of some preliminary work, in which we made a study of the relation of the enzymes contained in milk to the ripening process of cheese. We aimed to exclude bacterial action in cheese and thus limit our study to the results produced by the enzymes present in the milk when made into cheese, including rennet-enzyme. In our previous work, we made no attempt to distinguish between the different enzymes in respect to their individual action in cheese-ripening. The object of the work described in this bulletin was, primarily, to ascertain to what extent the proteolytic phenomena of cheese-ripening are due to the action of an enzyme contained in the rennet-extract used in cheese-making.

It has been quite generally believed that the rennet-extracts used in the manufacture of cheese contain not less than two enzymes or ferments, called rennin and pepsin, one ferment coagulating milk-casein and the other converting milk-casein and paracasein, under favorable conditions, into soluble forms of nitrogen compounds. The present tendency, however, is in the direction of the belief that both kinds of action are due to the presence of only one enzyme. The presence of a proteolytic ferment in rennet-extract is readily understood, when we consider its source, which is the stomach of a suckling calf.

For years the weight of opinion was against the belief that rennet has any other function in cheese-making than simply to coagulate milk-casein. In Bulletin No. 54, page 267, the results of some experiments made at this Station in 1892 are given, and it was shown that cheese made with larger amounts of rennet furnished greater quantities of soluble nitrogen compounds than did cheese made with smaller amounts of rennet. In 1899 some additional work was done, confirming the results previously obtained. Babcock, Russell and Vivian[1] have made a very thorough investigation of this subject, showing that, in the case of normal cheese, increased use of rennet resulted in a more rapid increase of soluble nitrogen compounds, especially

[1] Annual Report. Wis. Exp. Sta., 17 : 102 (1900).

of those nitrogen compounds grouped under the names of caseoses and peptones They also made cheese from milk to which purified commercial pepsin had been added and found similar chemical changes taking place in the cheese thus made. They concluded from these experiments with normal cheese that rennet exerts a digestive influence on casein, due to the presence of peptic enzymes contained in rennet-extracts, the action of which is intensified by the development of acid in the cheese-curd. Jensen,[2] working independently and along quite different lines, reached the same conclusions at the same time.

In the case of the work previously done here and elsewhere, the effect of rennet-ferment has not been studied apart from the action of other factors that are present in normal cheese-ripening. So far as our present knowledge goes, the different agencies taking part in the normal process of cheese-ripening are the following: (1) Some acid, usually lactic; (2) enzymes present in the milk before it is made into cheese; (3) an enzyme contained in the rennet-extract added to milk in the cheese-making process; and (4) micro-organisms, chiefly bacteria. In previous studies of the effect of rennet-ferment on cheese-ripening, some or all of these factors have been present, so that the specific action of rennet has had to be inferred rather than been clearly proved. It has been the special aim of our work to study the action of the rennet-ferment as far as possible apart from the other agencies of cheese-ripening. Under these conditions, we have studied the action of rennet-extracts in cheese-ripening,—(1) without acid, (2) in the presence of acid, (3) without salt, and (4) with salt. In addition, we have studied the action of rennet-extracts of different ages upon the casein of milk, and also the proteolytic action of commercial pepsin on milk-casein and in the process of cheese-ripening. We have also studied the action of rennet-enzyme and pepsin on paracasein dilactate.

DESCRIPTION OF EXPERIMENTAL WORK.

DIFFICULTIES INVOLVED IN THE WORK.

In order to destroy all enzymes present in milk, our general plan of procedure has been to heat the milk to a temperature

[2] *Landw. Jarhb. d. Schweiz.*, **14**: 197 (1900).

varying in different cases from 85° C. to 98° C. (185° F. to 208° F.). Then, in order to prevent possible contamination by the entrance of enzyme-producing organisms, the milk, after being heated and cooled, has been treated with 3 to 5 per ct. of chloroform by volume, previous to being made into cheese. The heating of milk to the temperature stated diminishes the readiness and completeness with which it is coagulated by rennet-extract, but the power of prompt coagulation by rennet can be restored by the addition of calcium chloride or carbon dioxide or any ordinary acid. In thus eliminating other factors of cheese-ripening than rennet-enzyme, we necessarily produce conditions that do not exist in normal cheese-making, such as (1) heated milk, (2) absence of milk-enzymes, (3) the use of calcium chloride or carbon dioxide, and (4) absence of enzyme-forming and acid-forming organisms. In a study carried on under such conditions, we cannot expect our results to be entirely comparable with results obtained under normal conditions; but we can secure data that enable us to determine the ability of the rennet-enzyme to cause proteolytic changes under the conditions of experiment employed. Later, we will inquire as to whether the introduction of such unusual conditions seriously affected the value of the results obtained, in their application to the process of normal cheese-ripening.

GENERAL OUTLINE OF EXPERIMENTAL WORK.

For each cheese made, we used from 40 to 75 pounds of normal milk, making a cheese adapted in size to the most convenient conditions of our work. Chloroform, when used, was introduced into the milk as soon as the milk had been heated to 85° C. to 98° C. (185° F. to 208° F.) and cooled to 29° C. (84° F.). The process of making cheese was then carried out in the usual manner. At the time of adding chloroform, samples of milk were taken out and carefully kept for chemical and bacteriological examinations, in order to ascertain whether any proteolytic enzymes remained active.

In experiments 44 to 47, calcium chloride was added to the milk to restore its coagulable power with rennet. In doing this, a solution was made containing 200 grams of pure calcium

chloride in 500 cc. of water, and we used 2.5 cc. of this solution for each kilogram of milk. Carbon dioxide was used in place of calcium chloride in experiments 48 to 51. In using this, we passed a vigorous stream of the gas through the milk for about 30 minutes previous to adding rennet. After several trials, we found that calcium chloride and carbon dioxide, used in the manner described, enabled the rennet-extract to coagulate the milk completely in 20 to 30 minutes. Hansen's rennet-extract was used at the rate of 2.5 liquid ounces for 1,000 pounds of milk (about 1 part of rennet-extract to 600 parts of milk by weight). In those experiments in which we compared the effect of the presence and absence of salt, a double portion of milk was generally used and the operation of cheese-making was carried on as usual to the point of salting, when the curd was divided into two approximately equal parts, one portion not being salted and the other portion receiving salt at the rate of 2 pounds of salt for 1,000 pounds of milk.

The cheeses were taken from the press and at once put under air-tight vessels in an atmosphere of chloroform, where they were kept during the period covered by our study. For additional details regarding the use of chloroform in cheese-making and cheese-ripening, see Bulletin No. 203, page 327.

The first series of experiments included 44 to 47. In these calcium chloride was used to restore the coagulability of the milk. Lactic acid was added in 45 and 46 and omitted in the others. Salt was added in 46 and 47 and omitted in 44 and 45. In all cases the milk was heated and treated with chloroform.

After a month, it was noticed that there was little indication of proteolytic change, and it was thought possible that the presence of calcium chloride might retard the action of the rennet-enzyme. It was then decided to repeat the experiments, using carbon dioxide in place of calcium chloride, and this second series included experiments 48 to 51.

In experiments 52 and 53, the milk was pasteurized at 85° C. (185° F.), carbon dioxide was added and the acid was furnished by a "starter," as in normal cheese-making. No chloroform was used. In 53 salt was used and omitted in 52.

In experiments 55, 56 and 57, the milk was pasteurized at 85° C. (185° F.) and cheese made with and without the use of commercial pepsin.

The details of the conditions of the individual experiments and of the results of chemical analysis are fully given in the Appendix.

THE RELATION OF RENNET-ENZYME TO CHEESE-RIPENING IN THE ABSENCE OF ACID.

In experiments 44, 47, 49 and 50, no acid was added and the conditions of experiment prevented the formation of acid, except possibly in minute quantities before the milk was heated. While the conditions of these experiments differ in some details, they were all as nearly alike as possible in respect to the absence of acid. Table I contains the results of chemical analysis when the cheese was fresh from press and when 12 months old.

TABLE I.—SHOWING EFFECT OF RENNET-ENZYME IN CHEESE-RIPENING IN ABSENCE OF ACID.

No. of experiment.	Age of cheese when analyzed.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—			
		Water-soluble nitrogen compounds.	Paracasein monolactate.	Paranuclein, caseoses and peptones.	Amides.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
43	Fresh.	4.67	2.46	3 22	1.45
43	12 mos.	9.70	3 33	5.61	4.09
44	Fresh.	1.93	2.44	1.93	0
44	12 mos.	6.25	2 72	2.96	3.29
47	Fresh.	3.67	2.90	3.67	0
47	12 mos.	6.41	3.46	3.08	3.33
49	Fresh.	10.95	5.24	9.92	1.03
49	12 mos.	10 34	4.27	5.16	5.18
50	Fresh.	10.12	5.72	8.57	1.55
50	12 mos.	9.67	3.02	5.74	3.93

If we compare the amount of water-soluble nitrogen compounds found in the fresh cheese and at the end of one year, we see readily that there was little or no advance in the proteolysis taking place in this period of time. It is also significant that there was little, if any, paracasein monolactate formed. The results of these experiments indicate that the rennet-ferment, in

the absence of acid, does little or no work in the formation of soluble nitrogen compounds in the process of cheese-ripening.

In passing, it may be well to speak of the sources of the soluble nitrogen compounds found in fresh cheese, that is, cheese about 24 hours old. The milk-albumin is a fairly constant source of soluble nitrogen. This is retained in cheese as a constituent of the whey, and the quantity retained depends largely upon the amount of whey held in the cheese. In ordinary normal cheese, the amount varies from 1.2 to 1.5 per ct. of the nitrogen in the cheese, but in extreme cases may exceed 2 per ct. In addition to milk-albumin, we have, as a source of soluble nitrogen compounds in fresh cheese, slight amounts of proteolytic products formed from casein and paracasein during the operation of cheese-making. The amount from this source varies with the conditions of manufacture. It is probable that paracasein and paracasein monolactate are slightly soluble in water and may contribute small amounts to the soluble nitrogen compounds of the fresh cheese.

In the cheeses used in most of the experiments described in this bulletin, excessive amounts of whey were unavoidably retained in the cheese, and the soluble nitrogen compounds found in the fresh cheese are therefore larger than in cheese holding less moisture.

ACTION OF RENNET-ENZYME IN THE PRESENCE OF ACIDS IN CHEESE-RIPENING.

In experiments 45, 46, 48 and 51, we added to the milk enough lactic acid to equal about 0.2 per ct. of the milk by weight. We thus had only two factors that could act as proteolytic agents in the cheese, the rennet-enzyme and the acid. The results of these experiments are given in Table II.

TABLE II.—SHOWING THE EFFECT OF RENNET-ENZYME IN THE PRESENCE OF ACID IN CHEESE-RIPENING.

No. of experiment	Age of cheese when analyzed.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—			
		Water-soluble nitrogen compounds.	Paracasein monolactate.	Paranuclein, caseoses and peptones.	Amides.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
45	Fresh	4.65	27.88	4.65	0
45	12 mos.	18.50	9.80	14.38	4.12
46	Fresh	5.40	26.62	3.96	1.44
46	12 mos.	18.50	11.97	14.02	4.48
48	Fresh	4.26	29.80	3.41	0.85
48	15 mos.	47.06	11.76	40.00	7.06
51	Fresh	3.89	22.92	3.10	0.79
51	15 mos.	19.32	12.83	15.06	4.26

In studying the data contained in Table II, we notice the following results:

(1) In every instance there was an increase of water-soluble nitrogen compounds. In most of the cases the increase was about one-third or one-fourth of what we find in a normal cheese, excepting No. 48, in which the amount was much nearer the results given by normal cheese. The increase in this case was probably due in part to the fact that during the first few weeks of ripening, this cheese was placed in a temperature of 21° C. (70° F.), while the others were kept at 15.5° C. (60° F.). It was probably still more due to the larger amount of moisture carried by 48, which was 10 to 15 per ct. greater than in 51.

(2) The increase of soluble nitrogen compounds was confined largely to the paranuclein, caseoses and peptones, the amount of amides remaining small. In normal cheese-ripening, we find these relations reversed, that is, the amides form a considerably larger part of the soluble nitrogen compounds than do the higher groups.

(3) In all of the cheeses, when fresh, we had a considerable and fairly uniform amount of paracasein monolactate, which compound was practically absent in the cheese containing no acid.

(4) The results embodied in Tables I and II may properly be interpreted as showing that the proteolytic action of the rennet-

enzyme in cheese-ripening is dependent upon the presence of acid.

ACTION OF RENNET-EXTRACTS OF DIFFERENT AGES AND OF COMMERCIAL PEPSIN ON MILK-CASEIN.

In considering the results obtained in cheese-ripening by the use of rennet-extract, the question may arise as to whether the observed proteolytic changes were due to rennet-enzyme alone or whether the rennet may not have contained some proteolytic bacterial enzymes produced in the rennet-extract previous to its use. In order to answer this question, we tried the effect of two samples of rennet-extract upon milk-casein, using one extract known to be in good condition and one known to be old and apparently in the first stages of putrefaction. These experiments were carried out in the following manner: We heated 8.6 liters of milk for 15 minutes at 85° C. (185° F.), and after cooling added 2 per ct. of chloroform by volume. Of this milk, we placed in each of several bottles 100 cc. In one case, we added to the neutral milk 0.22 cc. of Hansen's fresh rennet-extract, and in another the same amount of old rennet-extract. In other bottles, we added, in addition to the rennet-extract, 0.5 cc. of pure concentrated lactic acid. For comparison, we placed in other bottles, with and without acid, the same amount of milk and 0.06 gram of Parke, Davis & Co.'s aseptic scale pepsin for each 7 grams of proteid contained in the milk. Duplicates were used in all cases. The contents of these bottles were kept at 15.5° C. (60° F.) and were examined at intervals both chemically and bacteriologically. With the exception of a single determination in the case of one bottle, the germ content was below 50 per cc., which undoubtedly represented spore forms.

The results of chemical analysis are given in the subjoined table.

The determinations of nitrogen in the form of amides were made by the use of phosphotungstic acid, since it has been shown[3] that, in the case of peptic digestion, phosphotungstic acid is a more satisfactory reagent than tannic acid, especially in solutions having an acid reaction. The amount of nitrogen originally in the milk was 0.561 per ct.

[3] New York Agr. Exp. Sta. Bul. No. 215, pp. 90 and 98 (1902)

TABLE III.—SHOWING THE ACTION OF RENNET-EXTRACTS OF DIFFERENT AGES ON MILK-CASEIN.

Kind of rennet extract used.	With or without lactic acid.	Age of milk when analyzed.	Nitrogen, expressed as percentage of nitrogen in milk, in form of — Soluble nitrogen compounds.	Caseoses and peptones.	Amides.
			Per ct.	*Per ct.*	*Per ct.*
....	....	Fresh	9.98	....	....
Fresh	Without	1 mo.	11.35	6.00	5.35
"	With	" "	29.80	22 22	7.58
Old	Without	" "	12.57	4.99	7.58
"	With	" "	25.23	18.55	6.68
Fresh	Without	3 "	15.86	7.17	8.69
"	With	" "	41.89	31.73	10.16
Old	Without	" "	17.02	8 95	8 07
"	With	" "	36.45	26.29	10.16
Fresh	Without	6 "	17.49	14.82	2.67
"	With	" "	47.15	41 17	5 98
Old	Without	" "	14.40	10.65	3.75
"	With	" "	40 83	35.74	5 09
Fresh	Without	9 "	18.98	13.63	5.35
"	With	" "	53 57	45.64	7 93
Old	Without	" "	17.03	12.13	4 90
"	With	" "	47.96	39.67	8.29
Commercial pepsin	Without	1 "	8 91	2.22	6.69
"	With	" "	33 51	25.93	7.58
"	Without	3 "	11.42	2.42	9.00
"	With	" "	44.47	34.22	10.25
"	Without	6 "	10.34	6.60	3.74
"	With	" "	48.76	44.74	4.02
"	Without	9 "	10.08	6.51	3 57
"	With	" "	56.96	48.05	8 91

The data embodied in Table III appear to be quite definite in respect to the following points:

(1) At any given time, the fresh rennet-extract had, in most cases, formed a larger amount of soluble nitrogen compounds than had the old extract. This was particularly true in acid solution. This result does not indicate that we had bacterial enzymes in the old rennet in addition to rennet-enzyme. The difference in action of the two rennet-extracts is not marked in the class of amido compounds. If the old extract contained bacterial enzymes, we should expect it to produce larger amounts of amido compounds. These results fail to show that the old

rennet-extract contained any proteolytic bacterial enzymes, as compared with the fresh extract.

(2) If we compare the results secured by the use of the purest commercial pepsin with those given by the rennet-extracts, we find that, in the presence of acid, there are formed soluble nitrogen compounds quite close in amount to those formed by rennet-extract. The amount of soluble nitrogen compounds formed in neutral solution was fairly stationary during the 9 months, while, in the case of the rennet-extracts, there was a slow increase. The amount of amido compounds was surprisingly uniform in the case of the pepsin and the rennet-extracts, in both neutral and acid reaction. These results suggest that the pepsin was able to account for all the changes observed in the case of the rennet-extracts in the presence of acid. If there had been proteolytic enzymes of bacterial origin in the rennet-extracts, we should have expected a larger amount of digestion of milk-casein, and particularly in the class of amido compounds.

(3) In the case of the rennet-extracts in neutral solution, we notice that there was a small, but noticeable increase of water-soluble nitrogen compounds not observed in the case of pure pepsin. This increase was confined mostly to the caseoses and peptones. This increase may be due to the presence of some proteolytic enzyme, able to act in neutral solution, present in the rennet-extracts besides the rennet-enzyme proper. Granting that there is regularly present such an extra enzyme in rennet-extract, it could have very little to do with cheese-ripening, since in our experiments with milk we had much larger proportions of rennet-extract than are used in cheese-making. We added to the milk about 14 times as much rennet-extract as we commonly use in cheese-making; and this amount remained in the milk all the time, while in cheese-making some of the rennet-ferment passes into the whey.

(4) The increased activity of rennet-extract as well as of pepsin in the presence of acid is very marked.

EXPERIMENTS IN THE USE OF COMMERCIAL PEPSIN IN CHEESE-RIPENING.

In experiments 55, 56 and 57, the cheeses were made without

chloroform in the normal way, except that the milk was pasteurized at 85° C. (185° F.) and hydrochloric acid was used in the place of lactic acid or a "starter." In 55, rennet-extract alone was used at the usual rate of 2.5 ounces for 1,000 pounds of milk. In 56, in addition to rennet-extract, we added 1 gram of Parke, Davis & Co.'s aseptic scale pepsin dissolved in water, and in 57, we used 15 grams of the pepsin and the usual amount of rennet-extract. We began to add the hydrochloric acid when the milk was at 29.5° C. (85° F.), the additions being made in quantities of 5 cc. to 20 cc. at intervals, until the milk coagulated in 30 seconds by the Monrad test. After the curd was cut, we added portions of 20 cc. of hydrochloric acid at intervals of 5 to 15 minutes. being guided by the general behavior of the curd. No salt was added to the curd. In other respects, the method of manufacture was normal. The cheeses were ripened at 15.5° C. (60° F.), and were analyzed at intervals. The detailed results of the chemical work can be found in the Appendix. In Table IV, we give the analytical results found in the fresh cheese and at the time of the last analysis.

TABLE IV.—SHOWING EFFECT OF COMMERCIAL PEPSIN IN CHEESE-RIPENING.

No. of experiment.	Age of cheese when analyzed.	Enzymes added.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—				
			Water-soluble nitrogen compounds.	Paracasein monolactate.	Paranuclein, caseoses and peptones.	Amides.	Ammonia.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
55	Fresh	Rennet extract.	4.76	65.45	2.41	2.36	0
55	6 mos.		28.37	17.14	15.87	6.35	2.00
56	Fresh	Rennet and 1 gr. pepsin.	6 97	36.76	4.11	2.86	0
56	6 mos.		29.80	17.04	16.47	7.10	1.91
57	Fresh	Rennet and 15 gr. pepsin.	25.00	59.53	22.80	2.20	0
57	3 mos.		46 67	11.61	41.00	5.68	0.49

In studying the results contained in Table IV, we notice:

(1) The use of 1 gram of commercial pepsin in addition to

rennet-extract slightly increased the proteolytic results in the cheese. This cheese contained considerably less moisture than 55 or 57.

(2) The use of 15 grams of commercial pepsin along with rennet-extract produced very marked results. This is strikingly evident in the fresh cheese, where we have 25 per ct. of the nitrogen in the cheese present in the form of water-soluble compounds, while in the case of experiment 55, in which rennet-extract only was used, the amount of soluble nitrogen compounds is less than 5 per ct. At the end of 3 months, we still have much more of the soluble nitrogen compounds in 57, the pepsin cheese, than we have in 55, the rennet-extract cheese, at the end of 6 months.

(3) In comparing the proteolytic factors in experiments 55 and 57, the conditions of work were such that the chief essential difference was the presence of pepsin in the latter, though 57 contained more moisture than 55. The observed difference in the chemical results could, therefore, be due only to pepsin, and this would be particularly true of the results obtained in the fresh cheese.

ACTION OF RENNET-ENZYME AND COMMERCIAL PEPSIN ON PARACASEIN DILACTATE.

We have already given the results of our study relating to the action of rennet-enzyme and of commercial pepsin on casein in milk and on casein monolactate, in the presence of chloroform. We have studied the action of these two enzymes also on the proteids of cheese made from pasteurized milk. We will now present the results of some work done in studying the action of these same enzymes on paracasein dilactate. Paracasein monolactate was extracted from several pounds of cheese by a 10 per ct. solution of sodium chloride and this was treated with acid, precipitating paracasein dilactate. Of this compound washed free from salt, we placed 25 grams, suspended in water, in each of several flasks and sterilized by heat. We then sterilized some solution of pepsin and rennet-extract by treating with 0.5 per ct. of formalin, containing 0.2 per ct. of formaldehyde. Accord-

ing to Bliss and Novy,[4] pepsin is not affected by a 1 per ct. solution of formaldehyde nor rennet by a 4 per ct. solution. In one set of flasks, we added to each 0.06 gram of the sterilized pepsin, and in each of the other set of flasks 0.5 cc. of the sterilized rennet-extract. Duplicates were used in all cases. These were examined bacteriologically and chemically at intervals for 3 months. The formalin was very effective in destroying bacterial forms. In some cases a few molds were found, but not in sufficient number to affect the work. The nitrogen in the material was 4.35 per ct.

TABLE V.—SHOWING EFFECT OF RENNET-ENZYME AND COMMERCIAL PEPSIN ON PARACASEIN DILACTATE.

Enzymes used.	Age when analyzed.	Nitrogen, expressed as percentage of nitrogen in mixture, in form of—				
		Water-soluble nitrogen compounds.	Paracasein monolactate.	Paranuclein caseoses and peptones.	Amides.	Ammonia.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Pepsin	2 weeks	33.68	2.30	....	....	0
Rennet	" "	34.95	2.30	....	....	0
Pepsin	1 mo.	41.61	....	37.87	3.74	0
Rennet	" "	43.68	....	40.00	3.68	0
Pepsin	3 "	55.75	....	46.55	9.20	0
Rennet	" "	57.25	....	49.53	7.72	0

From the data contained in Table V, we can see that the results of our work indicate that:

(1) Both pepsin and rennet-enzyme exerted a marked proteolytic effect upon the paracasein dilactate, digesting about one-third of it in 2 weeks and considerably over one-half in 3 months. While the rennet-enzyme appears somewhat more active in forming water-soluble nitrogen compounds, the actual difference is small.

(2) Both enzymes formed amides in small quantities, but neither produced any ammonia.

(3) If we compare the results in Table V with those in Table III, we find that at the end of 1 and 3 months, more proteolysis occurred in this experiment than in the presence of chloroform. This is true of both enzymes. This suggests that the chloroform

[4] *Jour. Experimental Med.*, **4**: No. 1 (1899)

may exert a retarding influence upon the action of pepsin and rennet. Malfitano[5] makes the statement that the action of pepsin is considerably diminished by chloroform. The difference noted in our work may be due to the greater amount of acid present in the experiment in Table V. However, both sets of experiments practically agree in showing small formation of amides and entire absence of ammonia.

EXPERIMENTS IN MAKING CHEESE FROM PASTEURIZED MILK WITH "STARTER."

For the purpose of comparison, it was regarded as desirable to have some cheeses made from pasteurized milk. The cheeses in experiments 52 and 53 were made for this purpose. We pasteurized 135 pounds of milk at 85° C. (185° F.), cooled it to 29° C. (84° F.), passed carbon dioxide gas through it for half an hour, introduced 4.5 pounds of a specially prepared lactic acid "starter," added Hansen's rennet-extract at the rate of 2.5 ounces for 1,000 pounds of milk, and then carried on the operation of cheese-making in the usual way. The curd was divided into two equal parts and one part, unsalted, was made into cheese No. 52, while the other portion, salted at the usual rate, was made into No. 53. Both cheeses were ripened at a temperature of 15.5° C. (60° F.).

As factors active in causing proteolytic changes, we had in the cheeses made in these two experiments (1) acid, (2) rennet-enzyme and (3) such micro-organisms as happened to be introduced with the "starter" and from the air of the room. As compared with a normal cheese, there were no milk-enzymes present and the biological factor would be expected to be considerably less marked. In comparison with the cheeses made in experiments 44 to 51, we had in 52 and 53 no chloroform, a difference that meant absence of a biological factor in the former case. In 52 and 53 the acid was furnished by a "starter," while in the other experiments artificial acid was added. In Table VI we give the results of chemical analysis made when the cheese was fresh from press and when 9 months old. The detailed analyses are given in the Appendix.

[5] *Ann. Inst. Pasteur*, **16**: 853 (1902).

TABLE VI.—SHOWING COMPOSITION OF CHEESE MADE FROM PASTEURIZED MILK.

No. of experiment.	Age of cheese when analyzed.	Nitrogen, expressed in percentage of nitrogen in cheese, in form of—				
		Water-soluble nitrogen compounds.	Paracasein monolactate.	Paranuclein, caseoses and peptones.	Amides.	Ammonia.
52	Fresh	2.92	12.83	2.92	0	0
52	9 mos.	28.87	5.57	13.20	15.67	1.44
53	Fresh.	3.33	9.88	3.33	0	0
53	9 mos.	22.20	4.71	12.38	9.82	1.18

In studying these results, we notice:

(1) There was an increase in all the different classes of water-soluble compounds during the 9 months of ripening.

(2) The amount of amido compounds was considerably in excess of the amounts found in cheese made with chloroform.

(3) Ammonia was formed in 52 and 53, while none was present in experiments 44 to 51.

(4) The increased amount of amido compounds and of ammonia observed in experiments 52 and 53, as compared with experiments 44 to 51, must be ascribed to the presence in the former of an active biological factor.

THE DESTRUCTION OF MILK-ENZYMES BY HEAT.

In our experiments in using pasteurized milk for studying the proteolytic action of rennet-enzyme in cheese and milk, we have stated that no enzyme was present in the milk when made into cheese except that added in the rennet-extract. It is well known that milk contains a proteolytic enzyme, as shown first by Babcock and Russell and confirmed by our own work and that of others. In studying the action of rennet-enzyme, it is essential that all other enzymes previously existing in the milk shall be rendered inactive. It is commonly held that these enzymes are destroyed at 85° C. (185° F.). After pasteurizing the milk used in our various experiments, we took the precaution to keep samples of the milk for examination. These samples were treated with 3.5 per ct. of chloroform by volume and determinations of the soluble nitrogen compounds were made at intervals. The results of this work are given in the accompanying table.

TABLE VII—SHOWING EFFECT OF HEAT ON PROTEOLYTIC ENZYMES IN MILK.

No. of experiment.	Temperature used in heating milk.	Age of milk when analyzed.	Soluble nitrogen expressed in percentage of nitrogen in milk.
	Degrees	*Months*	*Per ct.*
General test	90°C. (194°F.)	13	4.26
" "	85°C. (185°F.)	8	10.8
" "	85°C. (185°F.)	7	9.7
45 and 46	95°C. (203°F.)	15	5.52
47	95°C. (203°F.)	16	5.5
51	98°C. (208°F.)	14	11.5

We have found that the percentage of soluble nitrogen in nearly fresh milk is often as high as 10 per ct. of the nitrogen in the milk. These results show that, during the long period of time indicated, no proteolysis had occurred and that we are justified in saying the milk was enzyme-free after heating.

EFFECT OF COMMON SALT ON ACTION OF RENNET IN CHEESE-RIPENING.

In Bulletin No. 203, page 241, we gave results showing that salt, in the proportion of about 1 per ct., the amount usually present in cheese, exerts a rather marked repressing influence upon the proteolytic action of those enzymes that are present in milk when made into cheese. We have also found that, in normal cheese, the addition of increased quantities of salt decreases the rapidity of proteolytic action. Some of our experiments were planned with a view to study the action of salt on cheese-ripening when rennet-enzyme is the only proteolytic factor present. In experiments 44 and 47, the results were negative because, in the absence of acid, no ripening change of any kind occurred. In experiments 45 and 46, the amount of soluble nitrogen was the same with and without salt, but was rather small in both cases, compared with normal cheese. In experiments 48 and 51, larger amounts of soluble nitrogen compounds were formed in the presence of salt. This may have been in part due to the fact that cheese 48 contained much moisture and was kept at a little higher temperature for the first few weeks. In experiments 52 and 53, the formation of soluble nitrogen compounds was less when salt was added; but, in these cases, we had present biological

factors not found in the other experiments. So far as these results go, they appear to indicate that, in cheese-ripening, salt, in the proportions commonly used, has little or no influence upon the action of rennet-enzyme, and that the retarding action observed in normal cheese, due to salt, comes from its influence upon other proteolytic agents. The results appear to us to call for additional work, before this point can be regarded as definitely settled. It may be mentioned in this connection that Chittenden and Allen[6] have shown that the action of pepsin in digesting blood-fibrin is diminished by the presence of common salt.

EFFECT OF ABNORMAL CONDITIONS PRESENT IN EXPERIMENTS.

We have already called attention to the difference of conditions present in the experiments described in this bulletin and those found in normal cheese. We will now consider these in more detail. These abnormal conditions found in our experiments, but not present in normal cheese, are the following: (1) Milk heated to 85° C. to 98° C. (185° F. to 208° F.) to destroy all enzymes originally existing in milk; (2) the use of calcium chloride or carbon dioxide gas to restore the coagulating property of milk-casein by rennet-extract; and (3) the use of chloroform to suppress all activity of organisms. The question naturally arises as to whether the introduction of these unusual conditions seriously affected the results obtained and, if so, in what manner and to what extent.

Does the pasteurizing of milk affect the proteolytic action of rennet-extract in relation to cheese-ripening?—A study of the data embodied in Tables I, II and III indicates that when the conditions were favorable for the action of rennet-enzyme or pepsin, we found more or less proteolysis taking place in cheese made from milk that had been heated as high as 98° C. (208° F.). In experiments 44, 47, 49 and 50, our results were negative, not because the milk had been heated, but because no acid was present, a condition that is essential for the action of rennet-ferment. In experiments 45, 46, 48 and 51, varying degrees of proteolysis were found but in these experiments acid was present, the milk

[6] Studies in Physiol. Chem. Yale Univ. **1**: 92 (1884-85).

having been heated as in the other cases. While we are unable, from any data known to us, to say whether rennet-enzyme would act any more vigorously in the case of cheese made from milk that had not been heated, we can say that the heating of milk does not prevent proteolysis, though possibly it may retard it somewhat, a point upon which we have no positive evidence. The fact that heating milk above a certain temperature weakens the action of rennet-enzyme in coagulating milk-casein may or may not be suggestive that the proteolytic function of rennet-ferment is also affected unfavorably. The vigorous digesting action of rennet-extract and of commercial pepsin on the casein of milk heated to 85° C. (185° F.) suggests that heat does not seriously affect the proteolytic action of rennet-enzyme; but the results of this experiment are not strictly applicable to results obtained with cheese, because we had much larger quantities of rennet-enzyme working in the milk than we had in the case of cheese.

Effect of calcium chloride and of carbon dioxide gas on the proteolytic action of rennet-extract in cheese-ripening.—In making a study of the series of experiments in which calcium chloride was used (44 to 47), we found that little or no digestion was taking place. It occurred to us that possibly this salt might have some repressing influence upon enzyme action. We then made a parallel series of experiments (48 to 51), in which the use of calcium chloride was replaced by carbon dioxide gas. In studying our results, we are unable to reach any definite conclusion in regard to the action of calcium chloride. Additional work is needed to settle this point definitely.

The use of calcium chloride is more convenient than that of carbon dioxide gas, but the latter is preferable in the following respects: (1) We obtain a curd more nearly normal in its general physical properties when carbon dioxide is used; (2) any excess of carbon dioxide is easily removed; (3) carbon dioxide is less likely to introduce permanently any abnormal chemical and biological conditions than is calcium chloride. So far as our results indicate, carbon dioxide by itself has no power to form with paracasein any salt-soluble compounds. This is shown particularly by experiment 49, Table I, in which neither acid nor salt was used and in which there was found increase of neither water-soluble nor salt-soluble compounds.

Effect of chloroform on the action of rennet-enzyme in cheese-ripening.—We have already called attention to the point that a comparison of the results contained in Tables III and V suggests that chloroform may exert some retarding influence upon the action of rennet-enzyme in cheese-ripening. In Bulletin No. 203, page 224, we published some results which appeared to indicate that chloroform has little or no effect upon galactase, but those results do not necessarily apply to any other enzyme. The work of Malfitano, already referred to, indicates that the action of a peptic ferment is retarded by chloroform.

DISCUSSION OF RESULTS.

In the work described in the preceding pages, we have studied the proteolytic action of rennet-enzyme under the following conditions:

(1) *In cheese containing rennet-enzyme as the only proteolytic agent, with and without acid, and also with and without salt.*—In these experiments (44 to 51), all milk-enzymes were destroyed by heating at 95° C. to 98° C. (203° F. to 208° F.), the coagulable property of the milk-casein was restored by the addition of either calcium chloride or carbon dioxide gas, and all organisms were rendered inactive by chloroform. Acid, when present, was furnished by addition of pure lactic acid.

(2) *In cheese containing rennet-enzyme together with acid-forming and some proteolytic organisms.*—In these experiments (52 and 53), the milk enzymes were destroyed by heating, acid was furnished by a lactic-acid "starter," but no chloroform was used. We thus had, as our only proteolytic agents, rennet-enzyme in the presence of acid and some liquefying organisms that were introduced in the "starter" or that got into the milk or curd during the operation of cheese-making.

(3) *In cheese containing commercial pepsin in addition to rennet-enzyme, together with hydrochloric acid and such organisms as were introduced during the process of making cheese.*—In these experiments (55 to 57), the milk enzymes were destroyed by heat and commercial pepsin added in different amounts.

(4) *In comparison with commercial pepsin on casein in milk, with and without acid.*—In these experiments, the milk-enzymes were

destroyed by heat and all organisms were rendered inactive by chloroform.

(5) *In comparison with commercial pepsin on paracasein dilactate.*—In these experiments, rennet-enzyme and commercial pepsin, sterilized by formaldehyde, were allowed to act upon sterile paracasein dilactate.

The results of these experiments appear to us to justify the following statements:

(1) In the case of every experiment made, whether with cheese or milk, there was little or no proteolytic action of either rennet-enzyme or commercial pepsin in the absence of acid; while there was marked action, though in varying degrees, in the presence of acid.

(2) In the absence of acid in cheese, no paracasein lactate is formed and little or no proteolysis occurs; in the presence of acid in cheese, or more strictly in the milk and curd, paracasein monolactate is formed and proteolysis takes place, with the rennet-ferment as the active agent. The ability of rennet-enzyme to convert paracasein into soluble nitrogen compounds appears to depend upon the presence of paracasin lactate. In cheese-making, therefore, the primary function of acid appears to be the formation of a chemical compound with paracasein, commonly paracasein monolactate but, in excess of acid, paracasein dilactate. The conversion of parcasein monolactate by rennet-enzyme into soluble nitrogen compounds is strongly suggested by the fact that, when the soluble nitrogen compounds increase, the paracasein monolactate decreases.

(3) In comparing rennet-enzyme and commercial pepsin in the case of cheese, milk and paracasein dilactate, the experiments that were strictly parallel have shown about the same extent of proteolytic action.

(4) In the case of both rennet-enzyme and commercial pepsin, the chemical work performed by the ferments is confined mainly to the formation of paranuclein, caseoses and peptones, while only small amounts of amides are formed, and no ammonia.

(5) Rennet-enzyme is a peptic ferment, as shown by the following characteristics: (*a*) neither rennet-enzyme nor pepsin causes much, if any, proteolytic change, except with the help of acid; (*b*) the quantitative results of proteolysis furnished by rennet-

enzyme and pepsin agree closely when working on the same material under comparable conditions; (*c*) the classes of soluble nitrogen compounds formed by the two enzymes are the same both qualitatively and quantitatively; (*d*) neither enzyme forms any considerable amount of amido compounds, and neither produces any ammonia; (*c*) the soluble nitrogen compounds formed by either enzyme are chiefly confined to the groups of compounds known as paranuclein, caseoses and peptones.

(6) The experiments made to determine the influence of salt on the proteolytic action of rennet-enzyme, while not conclusive, suggest that salt has little or no effect upon the action of rennet-enzyme in cheese-ripening.

(7) In obtaining our results relating to the study of the function of rennet-enzyme in cheese-ripening, we were necessarily compelled to work under conditions more or less abnormal as compared with the conditions commonly present in cheese-making. The effect of such unusual conditions would tend, if they had influence at all, to diminish the proteolytic action of rennet-enzyme. We are, therefore, justified in believing that our results represent the minimum effect of rennet-enzyme in cheese-ripening and that, under normal conditions, it takes, if anything, a larger part than that indicated by our experiments.

(8) In some experiments, we eliminated all milk-enzymes and all active forms of organisms contained in the milk before making it into cheese. In some cases, we had rennet-enzyme in the presence of acid as the only proteolytic agent in the cheese; in others, we had the same conditions and, in addition, such proteolytic organisms as chanced to get into the milk and curd during the process of cheese-making. In the latter case (52 and 53), larger amounts of amides were formed, and some ammonia; while, in the presence of rennet-enzyme alone, no ammonia was formed and only small amounts of amido compounds. When we compare normal cheese with cheese containing only rennet-enzyme, we find the same difference, except that it is more pronounced, as we should expect. Hence, the special work done by the rennet-enzyme as a factor in cheese-ripening is that of a peptic digestion, forming groups of water-soluble nitrogen compounds, intermediate in complexity of structure between paracasein and the amido compounds, viz., paranuclein, caseoses and peptones.

In normal cheese, we find an accumulation of amides and ammonia, as the cheese grows older and a corresponding diminution of the compounds previously formed. The formation of all the ammonia and of a large proportion of the amides found in ripened cheese must be due to some agency other than rennet-enzyme, and the only other agents present, besides milk-enzymes, that can do this work appear to be organisms or their enzymes. The first stage in normal cheese-ripening is essentially a peptic digestion of paracasein monolactate. Gradually amides are formed and later ammonia. It is probable that the first chemical work done in normal cheese-ripening is the conversion of paracasein monolactate by rennet-enzyme into paranuclein, caseoses and peptones. The question naturally arises as to whether these compounds must be formed before other agents can take part in the work and carry it along farther, producing amides and ammonia. We are at present engaged in studying this phase of the problem.

9. When rennet-enzyme was the only digesting agent in cheese, we were unable in any case to find the slightest traces of cheese flavor. Apparently, we must look to other sources for this important product of cheese-ripening.

APPENDIX.

It has been considered desirable to present in greater detail the data relating to the conditions of the experiments and to the analytical results, in order that those who are especially interested in the work may have access to these details.

CONDITIONS OF EXPERIMENTS IN CHEESE-MAKING.

In experiments 44 to 53 and 55 to 57, rennet was used at the uniform rate of 2.5 ounces for 1000 pounds of milk, and salt, when added, was used at the rate of 2 pounds for 1000 pounds of milk. In all experiments, the usual conditions of manufacture were followed as closely as possible. Chloroform, when used, was added in quantities to equal 3 to 5 per ct. of the milk by volume. The cheeses were in most cases cured at 15.5° C. (60° F.). We give in the following table the other details. The + sign shows that a certain condition was present, while the 0 sign shows that the condition in question was not present.

CONDITIONS OF MANUFACTURE OF EXPERIMENTAL CHEESES.

No. of experiment.	Date of making cheese.	Chloroform used.	Cheese salted.	Kind of acid used.	Milk heated.	Calcium chloride used.	Carbon dioxide used.	Pepsin used.	Pounds of milk used.
					Temp.				
44	Nov. 11, 1901	+	o	o	98° C	+	o	o	50
45	" 21, "	+	o	Lactic	"	+	o	o	125
46	" 22, "	+	+	Lactic	"	+	o	o	
47	" 23, "	+	+	o	"	+	o	o	50
48	Dec. 24, "	+	+	Lactic	"	o	+	o	40
49	" 24, "	+	o	o	"	o	+	o	75
50	Jan. 4, 1902	+	+	o	"	o	+	o	
51	" 7, "	+	o	Lactic	"	o	+	o	40
52	" 13, "	o	o	Starter	"	o	+	o	135
53	" 14, "	o	+	Starter	"	o	+	o	
55	July 9, "	o	o	Hydrochloric	85°	o	o	o	286
56	" 11, "	o	o	Hydrochloric	"	o	o	1 gram	279
57	" 13, "	o	o	Hydrochloric	"	o	o	15 grams	280

DETAILS OF CHEMICAL ANALYSES.

The methods of analysis employed are those fully described in Bulletin No. 215 of this Station. Even with the exercise of extreme precaution, it is difficult always to secure from the same cheese samples that will give uniform analytical results, since different portions of a cheese may vary in composition. Such inconsistencies as appear in different analyses of the same cheese are to be attributed largely to variations of different samples. At the same time, it should be remembered that our methods of separation are far from perfect. In some cases, we give the results secured for amido compounds with both reagents, phosphotungstic acid and tannic acid. In peptic digestions, we regard the determination of amides by phosphotungstic acid as being much nearer the actual truth.

EXPERIMENT 44.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of —					
				Para-casein mono-lactate.	Total water-soluble nitrogen compounds.	Para-nuclein, caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Fresh...........	47.00	5.9	3.11	2.44	1.93	1.93	......	0	0
1 week........	47.70	6.1	3.18	2.52	4.40	3.14	......	1.26	0
2 "	46.00	5.9	3.11	2.25	3.34	2.28	......	0.96	0
1 month........	46.70	6 1	3.13	2 43	4.22	4 22	......	0	0
2 "	44.60	8.8	3.24	2.72	3.77	3.77	......	0	0
6 "	47.50	6.4	3.30	3.39	7.39	3 46	......	3.94	0
9 "	46.50	7.2	3.39	2.36	6.84	2 71	2 95	4.13	0
12 "	45.20	7 0	3.68	2.72	6.25	2.96	3.29	3.29	0

EXPERIMENT 45.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Para-casein mono-lactate.	Total water-soluble nitrogen compounds.	Para-nuclein, caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
Fresh...........	41.65	10.6	3.12	27.88	4.65	3 37	......	1.28	0
1 Week........	42 00	10.4	3 13	27.16	3.83	3 83	......	0	0
1 Month........	42.25	9.6	3.12	22.24	7.57	4.68	......	2.89	0
2 "	39.25	12.4	3.15	16.29	11.30	10 67	......	0.63	0
6 "	41.50	11.0	3.24	18.06	17.53	14 14	......	3.39	0
9 "	40.50	12.0	3.32	19.64	16.15	13.74	2 41	7.53	0
12 "	40.00	12.0	3.57	9.80	18.50	14.38	4.12	4.90	0

EXPERIMENT 46

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—					
				Paracasein monolactate.	Total water-soluble nitrogen compounds	Paranuclein, caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Fresh	47.70	9.6	2.78	26.62	5.40	3.96	......	1.44	0
1 Week........	46.60	9.8	2.79	25.09	3.44	3.44	......	0	0
1 Month.......	44.40	9.6	2.84	22.19	9.71	8.16	......	1.55	0
2 "	43.90	11.6	2.89	28.52	11.66	11.21	......	0.45	0
6 "	46.00	10.4	2.97	19.06	18.90	14.72	......	4.21	0
9 "	44.00	10.8	3.04	19.94	17.17	15.52	1.65	6.58	0
12 "	......	......	3.35	11.97	18.50	14.02	4.48	4.48	0

EXPERIMENT 47.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Paracasein monolactate.	Total water-soluble nitrogen compounds	Paranuclein, caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
Fresh..........	48.50	9.8	2.62	2.90	3.67	3.67	......	0	0
1 week.........	47.40	10.4	2.72	2.21	3.60	3.60	......	0	0
1 month........	47.40	10.2	2.67	2.10	4.00	2.88	......	1.12	0
2 "	47.30	......	2.70	3.12	5.78	5.41	......	0.37	0
6 "	47.00	11.0	2.77	3.03	8.81	5.20	......	3.61	0
9 "	46.00	11.6	2.84	2.47	5.99	3.88	2.11	3.35	0
12 "	......	......	3.12	3.46	6.41	3.08	3.33	3.52	0

EXPERIMENT 48.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Paracasein monolactate.	Total water-soluble nitrogen compounds	Paranuclein, caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
Fresh..........	53.00	8.9	2.35	29.80	4.26	3.41	......	0.85	0
2 weeks........	51.40	11.2	2.30	27.40	13.04	11.91	......	1.13	0
1 month........	50.00	10.2	2.51	27.09	13.95	11.20	......	1.75	0
3 "	50.54	12.0	2.41	27.22	32.37	29.88	......	2.49	0
6 "	49.20	13.2	2.48	25.41	27.99	24.36	......	3.63	0
9 "	49.50	13.0	2.48	20.97	36.30	32.67	......	3.63	0
12 "	......	......	2.62	12.98	40.84	35.88	4.96	6.30	0
15 "	......	......	2.55	11.76	47.06	40.00	7.06	9.40	0

EXPERIMENT 49.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Paracasein monolactate.	Total water-soluble nitrogen compounds	Paranuclein, caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
Fresh..........	55.60	6.6	2.52	5.24	10.95	9.92	......	1.03	0
2 weeks........	55.00	6.4	2.61	4.75	9.43	8.43	......	1.00	0
1 month........	54.20	5.8	2.64	2.54	5.76	5.76	......	0	0
3 "	51.05	8.0	2.79	3.73	9.18	5.95	......	3.23	0
6 "	49.40	8.5	3.12	2.56	10.00	7.11	......	2.89	0
9 "	48.60	8.8	3.33	......	7.81	4.61	3.20	3.90	0
12 "	......	......	3.28	4.27	10.34	5.16	5.18	4.57	0

EXPERIMENT 50.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of —					
				Para-casein mono-lactate.	Total water-soluble nitrogen compounds	Para-nuclein caseoses and peptones.	Amides by phospho-tungstic acid.	Amides by tannic acid.	Ammonia.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Fresh	54.50	6.7	2.59	5.72	10.12	8.57	......	1.55	0
2 weeks	55.00	6.5	2.55	5.10	9.49	7.53	......	1.96	0
1 month	52.50	8.4	2.52	3.97	6.35	6.35	......	0	0
3 "	50.30	9.6	2.79	3.16	9.90	6.30	......	3.60	0
6 "	51.30	9.0	3.06	3.14	12.75	9.81	......	2.94	0
9 "	51.50	9.0	3.20	2.81	7.50	3.75	3.75	3.75	0
12 "	......	......	3.31	3.02	9.67	5.14	4.53	5.14	0

EXPERIMENT 51.

Fresh	38.15	13.2	3.29	22.92	3.89	3.11	......	0.79	0
2 weeks	38.60	13.2	3.32	23.68	5.66	5.03	......	0.63	0
1 month	37.30	16.0	3.10	22.97	5.30	5.30	......	0	0
3 "	37.30	16.5	3.27	22.02	11.25	8.50	......	2.75	0
6 "	39.00	15.8	3.27	17.62	12.48	10.95	......	1.53	0
9 "	38.70	16.0	3.48	15.23	13.22	10.35	2.87	3.45	0
12 "	......	......	3.42	12.87	15.50	10.53	4.97	4.97	0
15 "	......	......	3.52	......	19.32	15.06	4.26	5.12	0

EXPERIMENT 52.

Fresh	42.75	0	3.43	12.83	2.92	2.92	......	0	0
2 weeks	39.20	0	3.68	11.68	7.45	4.73	......	2.72	0.54
1 month	39.78	0	3.80	8.95	10.90	7.21	......	3.69	0.68
3 "	35.10	0	4.08	8.78	17.21	8.21	......	9.00	0.32
6 "	34.55	0	4.48	8.20	24.11	15.11	9.00	16.07	1.00
9 "	30.73	0	4.85	5.57	28.87	13.20	15.67	22.90	1.44

EXPERIMENT 53.

Fresh	45.73	0	3.24	9.88	3.33	3.33	......	0	0
2 weeks	41.08	0	3.55	11.27	8.14	4.48	......	3.66	0.56
1 mo.	41.52	0	3.61	8.80	11.08	6.65	......	4.43	0.72
3 "	36.75	0	3.97	7.21	16.90	7.48	......	9.42	0.15
6 "	36.41	0	4.49	3.15	20.72	13.61	7.11	12.47	1.11
9 "	27.10	0	5.09	4.71	22.20	12.38	9.82	16.30	1.18

EXPERIMENT 55.

Age of cheese when analyzed.	Per ct. of water in cheese.	Per ct. of chloroform in cheese.	Per ct. of nitrogen in cheese.	Nitrogen, expressed as per centage of nitrogen in cheese, in form of — Paracasein monolactate.	Total water-soluble nitrogen compounds	Paranuclein caseoses and peptones.	Amides by phosphotungstic acid.	Amides by tannic acid.	Ammonia.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Fresh	38.61	0	3.82	65.45	4.76	2.41	2.35	2.36	0
1 mo.	38.05	0	4.05	23.95	16.99	14.64	2.35	4.94	0.49
3 "	34.25	0	4.24	15.10	29.25	25.12	4.13	10.61	0.61
6 "	28.84	0	5.04	17.14	28.37	22.02	6.35	10.50	2.00

EXPERIMENT 56.

Fresh	33.75	0	4.19	36.76	6.97	4.11	....	2.86	0
1 mo.	31.82	0	4.48	23.22	18.08	16.29	1.79	6.92	0.54
3 "	28.31	0	4.64	15.09	26.08	21.34	4.74	11.21	0.56
6 "	24.30	0	5.07	17.04	29.80	22.70	7.10	11.42	1.91

EXPERIMENT 57.

Fresh	47.35	0	3.36	59.53	25.00	15.18	2.20	9.82	0
1 mo.	38.33	0	3.80	18.16	43.95	40.00	3.95	26.06	0.68
3 "	31.12	0	4.05	11.61	46.67	41.00	5.68	19.76	0.49

EXPERIMENTS IN CURING CHEESE AT DIFFERENT TEMPERATURES.*

L. L. VAN SLYKE, G. A. SMITH AND E. B. HART.

SUMMARY.

(1) Object of Experiment.—The investigation was undertaken by the Dairy Division of the U. S. Department of Agriculture with the coöperation of this Station, its object being to study on a commercial scale, under commercial conditions, the influence of different temperatures upon cheese during the curing process.

(2) Plan of Experiment.—Cheese was secured, representing the product of the States of New York, Pennsylvania and Ohio, and placed in cold storage at the temperatures of 40° F., 50° F. and 60° F. These were examined commercially by a committee of experts when first placed in cold storage and later after being in cold storage 10, 20, 28 and 35 weeks. Cheeses of different size were used, weighing 70, 65, 45, 35 and 12.5 pounds. Also, in one case, cheeses were covered with coating of paraffin. Chemical analyses were made at intervals.

(3) Loss of Weight.—The loss of weight increased with increase of temperature, being on an average in 20 weeks 3.8 pounds per 100 pounds of cheese at 40° F., 4.8 pounds at 50° F. and 7.8 pounds at 60° F. The large-sized cheeses lost less weight per 100 pounds than the smaller-sized ones.

(4) Results of Scoring Cheese.—Cheese cured at 40° F. was superior in quality to the same kind cured at higher temperatures. That cured at 50° F. was superior in quality to that cured at 60° F. The general averages of the scores at the end of 20 weeks were as follows: 95.7 at 40° F., 94.2 at 50° F. and 91.7 at 60° F. The differ-

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ence in quality was confined in most cases to flavor and texture, the color and finish being little or not at all affected in cheese that was in good condition at the beginning.

(5) Effects of Covering Cheese with Paraffin.—The commercial qualities of the cheese were favorably influenced after 6 months in the case of those covered with paraffin, especially flavor. The loss of moisture was greatly lessened, amounting only to a fraction of a pound for 100 pounds of cheese at 40° F. and 50° F., and being only about one-fifth the average loss found at 60° F. with cheese not so treated. The cheeses were also perfectly clean and free from mold, while all the cheeses not treated with paraffin were covered with mold.

(6) Some Practical Applications.—Curing cheese at low temperatures increases the amount of cheese to sell, by preventing loss of moisture, and covering cheese with paraffin increases still more the yield of marketable cheese. This saving amounts to several dollars a ton. Also, the improved quality of cheese cured at low temperatures enables such cheese to bring a higher market price.

(7) Results of Chemical Analysis.—The amount of certain water-soluble nitrogen compounds in cheese, such as caseoses, peptones, amides and ammonia, is used as a means for measuring chemically the degree of ripeness in cheese. The amount of water-soluble nitrogen compounds increases with the age of cheese and with the temperature at which the cheese is cured.

INTRODUCTION.

The investigation described in this bulletin had its origin with the U. S. Department of Agriculture, and was under the charge of Henry E. Alvord, Chief of the Dairy Division of the Bureau of Animal Industry. This Station was asked to cooperate in the work, which it did by securing parties to furnish the cheese used in the investigation, by suggesting conditions of experiment, by assisting in the commercial examination of the cheese from time to time, by making analyses of the cheeses at intervals and by keeping the records of the work. B. F. Van Valkenburgh, of New York City, gave immediate personal supervision to the work on the part of the U. S. Department of Agriculture.

The plan of the experiment was to secure cheeses representing the states of New York, Pennsylvania and Ohio, to place these in cold storage at different temperatures, to have commercial examinations made from time to time by a committee of chosen experts, to weigh the cheeses at intervals and to make chemical analyses of them. The object of this work was to study during the curing process the effect of different temperatures and the effect of covering cheese with paraffin, upon (1) the commercial quality of the cheese, (2) the loss of weight, and (3) the chemical changes taking place.

DETAILS OF INVESTIGATION.

DESCRIPTION OF SOURCES AND CHARACTER OF DIFFERENT LOTS OF CHEESE USED IN THE EXPERIMENT.

The arrangements for carrying on the experiment were not completed until the latter part of September, when it was somewhat difficult to secure large-sized cheeses, because most of the factories were making only the small home-trade size. We were able, however, to get the makers in two cases to make the large-sized cheeses for this special work, but they were not of the best quality in every respect.

Lot I (B 970) comprised 21 cheeses, averaging 64 lbs. each in weight, made by A. B. Hargrave, at Heuvelton, St. Lawrence county, N. Y. These were made from the mixed milk of September 26, which contained 3.8 per ct. of fat. The milk was

ripened to $4\frac{1}{2}$ spaces by the Marschall rennet test at a temperature of 86° F. Rennet-extract was used at the rate of $2\frac{1}{2}$ ounces for 1000 lbs. of milk. The milk began to thicken in 15 minutes. The curd was heated to 98° F. in 45 minutes. One hour and 20 minutes later the curd showed one-eighth of an inch of fine threads by the hot-iron test, when the whey was removed. The curd was then packed, drained and kept for 3 hours, after which it was milled, salted at the rate of 2 lbs. of salt for 1000 lbs. of milk, cooled to 80° F. and put in press.

This lot of cheese was shipped to New York on September 30 and placed in cold storage on October 6th.

Lot II (B 973) comprised 40 boxes of cheese, made by J. E. Case, at Turtle Point, Pa., during the third week in September. These were secured through W. C. Dunham & Co., Cuba, N. Y. They averaged 45 lbs. each in weight. It was found impossible to get a special lot of cheese made in Pennsylvania for this work and so it was decided to take some already made. These cheeses were therefore older when put into cold storage and did not get the full benefit of ripening at lower temperatures. In making the cheese, a starter of lactic ferment was used and the milk ripened to about 5 spaces by the Marschall test at a temperature of 86° F. Rennet-extract was used at the rate of $2\frac{1}{2}$ ounces for 1000 lbs. of milk and the curd was cut in about 45 minutes. The subsequent heating was carried to about 100° F. The whey was removed as soon as the curd strung on a hot iron. After milling, the curd was allowed to stand about half an hour before salting, with frequent stirring, and then cooled to 90° F. Salt was added at the rate of $2\frac{1}{2}$ lbs. for 1000 lbs. of milk used.

This lot of cheese was placed in cold storage on October 6th.

Lot III (B 977) consisted of 44 cheeses, averaging in weight about 34 lbs. each. They were made at the Sulphur Spring Factory, Lowville, Lewis county, N.Y., by J. H. Searl, from the mixed night and morning milk of September 26; half were uncolored (A) and half were colored (B). The mik contained 4 per ct. of fat and 12.60 per ct. of solids. The milk was ripened to $3\frac{1}{2}$ spaces by the Marschall test at 84° F. Rennet-extract was used at the rate of $2\frac{1}{2}$ ounces for 1000 lbs. of milk. The curd was cut in 25 minutes, and 15 minutes later heat was applied,

the temperature of 98° F. being reached in 50 minutes. Forty minutes later the whey was removed, as the curd showed one-eighth of an inch of string by the hot-iron test. After packing and draining in the usual way, the curd was milled about 4 hours after the removal of whey. Salt was added at the rate of 2 lbs. for 1000 lbs. of milk used, the curd was cooled to 80° F. and then put in press.

This lot of cheese was shipped to New York October 1 and placed in cold storage October 7th.

Lot IV (B 982) consisted of two different sizes of cheese, made by G. S. Alger at Martinsburg, Lewis county, N. Y.; there were 20 colored cheeses (A), each weighing about 65 lbs., and 28 cheeses of so-called Stilton size (B), each weighing about $12\frac{1}{2}$ lbs. The cheese was made from mixed milk of September 29, containing 4 per ct. of fat and 12.60 per ct. of solids. The conditions of manufacture were normal.

This lot of cheese was shipped on October 3 and placed in cold storage on October 8.

Lot V (B 986) comprised 34 cheeses made by E. S. Rice at Triumph, Ohio, averaging in weight about $36\frac{1}{2}$ lbs. each. Rennet-extract was added at the rate of 3 ounces for 1000 lbs. of milk at 86° F. The curd was cut in 30 minutes and then heated to 104° F. in about 30 minutes, the whey being drawn an hour and a half later. Salt was added at the rate of $2\frac{1}{4}$ lbs. for 1000 lbs. of milk used.

This lot was shipped October 7 and placed in cold storage October 13, 1902.

Lot VI (B B 69 and B B 69 BB 69) consisted of 40 cheeses furnished by the kindness of J. S. Martin & Co. Each cheese weighed about 70 lbs. These cheeses were not included in the scope of the investigation as planned by the U. S. Department of Agriculture. It was desired by this Station to study the effect of covering cheese with paraffin upon the curing process. By the courtesy of the U. S. Department of Agriculture, the use of the curing rooms designed for the original investigation was permitted for this additional experiment. The same conditions of temperature, inspection, weighing and analysis were observed in the case of these cheeses as in the case of the other lots.

J. S. Martin & Co. were so much interested in the subject of covering cheese with paraffin that they generously furnished at their own risk all the cheeses used for this work. The cheese contained in this lot represented two different dates of manufacture one week apart, October 10 (A) and October 17 (B).

This lot of cheese was made by H. Petrie of Turin, Lewis county, N. Y. The milk, of good quality in every respect, was warmed to 86° F. and a carefully prepared sour-milk starter added. It was then ripened to about 4 spaces by the Marschall test. Rennet-extract was added at the rate of 2½ ounces for 1000 lbs. of milk. In 25 to 30 minutes the curd was cut, the cutting being somewhat fine, after which careful stirring was begun and continued until the pieces of curd were well separated and beginning to shrink. Heat was then applied, the temperature of 98° F. being reached in about 45 minutes. Stirring was continued until the curd strung on the hot-iron one-eighth of an inch, when the whey was removed. The curd was then matted, cut into pieces about 3 by 6 by 6 inches and turned at intervals of 6 or 8 minutes, until the curd was well drained and solid. The curd was then piled until it acquired a smooth, velvety feeling, after which it was milled, spread out, stirred and cooled, until fat started from it when squeezed in the hand. It was then salted at the rate of 2 lbs. of salt for 1000 lbs. of milk used, and finally put in press. Light pressure was applied at first, just enough to make the curd hold together in the form of the mold. At the end of one hour the cheeses were removed from the hoops, the cloths and outside of the cheeses rinsed with warm water, replaced in press and pressure applied for 18 hours.

This lot was placed in cold storage October 24, half of the number being covered with paraffin (Ap and Bp) and half being in the usual condition (An and Bn).

LENGTH OF EXPERIMENT.

In February, the cheese stored at 60° F. was removed and sold. In April, the cheese stored at 50° F. was placed on the market, and also most of the cheese kept at 40° F. Some of the cheeses that had been held at 40° F. were retained and kept until June 1st, when they were sold, except a few that were kept and placed at a temperature of 32° F. for further work.

DISTRIBUTION OF CHEESES IN COLD STORAGE.

Arrangements were made with the Merchants' Refrigerating Co., of 31 North Moore street, New York City, to provide rooms for, and take care of, the different lots of cheese. Rooms were provided in which the temperatures could be controlled and kept at 40° F., 50° F. and 60° F. Automatic records were arranged in each room, showing the condition of temperature continuously. The variations of temperature from the desired point were very slight, since the control was extremely satisfactory.

The different lots of cheese were distributed in the different temperatures in the manner indicated by the following table:

TABLE I.—DISTRIBUTION OF CHEESE AT DIFFERENT TEMPERATURES.

Number of lot.	Cheeses at 40° F.	Cheeses at 50° F.	Cheeses at 60° F.
	No.	*No.*	*No.*
I.	10	6	5
II.	18	12	10
III. White (A)	11	6	5
III. Colored (B)	11	6	5
IV. Large (A)	9	6	5
IV. Stiltons (B)	16	8	4
V.	19	8	7
VI. An and Bn	5	3	2
VI. Ap and Bp	5	3	2

RESULTS OF INVESTIGATION.

LOSS OF WEIGHT.

The following table gives the weights of the cheese kept at the different temperatures for the periods of time indicated:

TABLE II.—SHOWING WEIGHTS OF CHEESE AT DIFFERENT PERIODS.

Number of lot of cheese.	Date of weighing.	Weight of cheese kept at temperature of—		
		40° F.	50° F.	60° F.
		Lbs.	*Lbs.*	*Lbs.*
I.	Oct. 6, 1902	645	384	325
"	Feb. 13, 1903	616	367	303
"	Apr. 10, 1903	611	361	....
"	June 1, 1903	600	....	....
II.	Oct. 6, 1902	811	535	448
"	Feb. 13, 1903	789	515	425
"	Apr. 10, 1903	783	511	....
"	June 1, 1903	774	....	....
III. A.	Oct. 7, 1902	378	207	170
" "	Feb. 13, 1903	362	195	155
" "	Apr. 10, 1903	357	192	....
" B.	Oct. 7, 1902	371	204	171
" "	Feb. 13, 1903	360	193	157
" "	Apr. 10, 1903	355	189	....
" "	June 1, 1903	348	....	....
IV. A.	Oct. 3, 1902	585	387	329
" "	Feb. 13, 1903	559	366	305
" "	Apr. 10, 1903	554	365	....
" "	June 1, 1903	545	....	....
" B	Oct. 8, 1902	197	99	50
" "	Feb. 13, 1903	188	91	44
" "	Apr. 10, 1903	184	88	....
" "	June 1, 1903	179	....	....
V.	Oct. 13, 1902	696	290	256
"	Feb. 13, 1903	664	271	233
"	Apr. 10, 1903	658	266	....
"	June 1, 1903	646	....	....
VI. An.	Oct. 24, 1902	358	211	143
" "	Feb. 13, 1903	349	206	137
" "	Apr. 10, 1903	346.7	202.7	....
" "	June 1, 1903	342.0	....	....
" Ap.	Oct. 24, 1902	356	212	142
" "	Feb. 13, 1903	355	211	140
" "	Apr. 10, 1903	354	210	....
" "	June 1, 1903	352.8	209 5	....
" Bn.	Oct. 24, 1902	352	....	....
" "	Feb. 13, 1903	340	....	....
" "	Apr. 10, 1903	336.5	....	....
" "	June 1, 1903	333.2	....	....
" Bp.	Oct. 24, 1902	358	208	138
" "	Feb. 13, 1903	357	207	136
" "	Apr. 10, 1903	356 6	207	....
" "	June 1, 1903	355.4	....	....

TABLE III.—SHOWING WEIGHT LOST BY CHEESE.

Number of lot of cheese.	Average weight of each cheese.	Age when placed in cold storage.	Age when weighed.	Pounds lost for 100 lbs. of cheese at—		
				40° F.	50° F.	60° F.
	Lbs.			*Lbs.*	*Lbs.*	*Lbs.*
I.	64	9 days...	20 weeks.	4.5	4.4	6.8
“	“	“ “ ...	28 “	5.3	6.0	....
“	“	“ “ ...	35 “	7.0	....	....
II.	45	18 days...	20 weeks.	2.7	3.7	5.1
“	“	“ “ ...	28 “	3.5	4.5	....
“	“	“ “ ...	35 “	4.5	....	....
III. A.	34	9 days...	20 weeks.	4.2	5.8	8.8
“ “	“	“ “ ...	28 “	5.6	7.2	....
“ B.	34	9 days...	20 weeks.	3.0	5.4	8.8
“ “	“	“ “ ...	28 “	4.3	7.4	....
“ “	“	“ “ ...	35 “	6.8	....	....
IV. A.	65	8 days...	20 weeks.	4.4	5.4	7.3
“ “	“	“ “ ...	28 “	5.3	5.7	....
“ “	“	“ “ ...	35 “	6.8	....	....
“ B.	12.5	8 days...	20 weeks.	4.6	8.1	12.0
“ “	“	“ “ ...	28 “	6.6	11.1	....
“ “	“	“ “ ...	35 “	9.1	....	....
V.	36.5	———	19 weeks.	4.6	6.6	9.0
“	“	———	27 “	5.5	8.3	....
“	“		34 “	7.2	....	....
VI. An.	70	7 days...	17 weeks.	2.5	2.4	4.2
“ “	“	“ “ ...	25 “	3.1	4.0	....
“ “	“	“ “ ...	32 “	4.5	....	....
“ Ap.	70	7 days...	17 weeks.	0.3	0.5	1.4
“ “	“	“ “ ...	25 “	0.6	0.9	....
“ “	“	“ “ ...	32 “	0.9	....	....
“ Bn.	70	14 days...	17 weeks.	3.4	....	....
“ “	“	“ “ ...	25 “	4.4	....	....
“ “	“	“ “ ...	32 “	5.3	....	....
“ Bp.	70	14 days...	17 weeks.	0.3	0.5	1.5
“ “	“	“ “ ...	25 “	0.4	0.5	....
“ “	“	“ “ ...	32 “	0.8	....	....

From the data contained in Table III, we are enabled to make the following statements:

(1) The cheese continued to lose water in nearly every case as long as weighings were made. This was true of all temperatures.

(2) The loss of weight was least at 40° F. and increased with increase of temperature. At the end of 20 weeks, the cheese in temperature 40° F. had lost on an average 3.8 lbs. per 100; that in 50° F., 4.8 lbs.; and that in 60° F., 7.8 lbs. The loss at temperature 40° F. was 1 lb. less than at 50° F. and 4 lbs. less

than at 60° F. In other words, the loss at 60° F. as compared with the loss at 50° F. was three times as great as was the loss at 50° F. compared with the loss at 40° F. The loss of weight was proportionally greater at higher temperatures.

(3) If we determine the average weekly loss from the data given in Table III, we find that during the first 20 weeks the loss was at the average rate of 3 ounces a week at 40° F., 3.8 ounces at 50° F. and 6.2 ounces at 60° F. From the 20th to the 28th week, the average weekly loss was 2.2 ounces at 40° F. and 3.2 ounces at 50° F. The cheese kept at 40° F. appeared to lose more moisture per week from April 10 to June 1 than previously.

(4) The size of cheese influences the loss of moisture. Small cheeses, other conditions being the same, lose a larger proportion of moisture in curing than do large cheeses, owing to the greater amount of surface relative to weight in the smaller cheeses. This tendency is shown by the following tabulated statement:

LOSS IN WEIGHT BY CHEESES OF DIFFERENT SIZES.

Average weight of each cheese.	Weight lost per 100 pounds of cheese in 20 weeks at		
	Temp. 40° F.	Temp. 50° F.	Temp. 60° F.
	Lbs.	*Lbs.*	*Lbs.*
70 lbs.	2.5	2.4	4.2
45 "	2.7	3.7	5.1
35 "	3.9	5.9	8.5
12½ "	4.6	8.1	12.0

It will be noticed that the variation is much less at 40° F. than at the higher temperature.

(5) The method of covering cheese with paraffin greatly reduces the loss of moisture. In VI, An and Bn, the cheeses were in their usual condition, while in VI, Ap and Bp, they were covered with paraffin, being dipped in melted paraffin when a few days old. The loss of moisture in cheese covered with paraffin was only 0.3 pound per 100 pounds of cheese in 20 weeks at 40° F., 0.5 pound at 50° F. and 1.4 pounds at 60° F. In the same kind of cheese not thus covered the loss of moisture was much greater at all temperatures. By covering cheese with paraffin,

a saving in loss of moisture can be effected, amounting to 5 or 6 pounds per 100 pounds of cheese at 60° F. and at 50° or below the total loss of moisture can be reduced to less than 1 pound per 100 pounds of cheese. In addition, the use of paraffin prevents the growth of molds. In every case, cheeses covered with paraffin were entirely clean, while the others were more or less heavily coated with molds.

RESULTS OF COMMERCIAL EXAMINATION OF CHEESE.

Arrangements were made to have the cheese examined at intervals by commercial experts who were to score the cheeses separately, the basis of a perfect cheese being 50 for flavor, 25 for texture, 15 for color and 10 for finish. The following well-known experts were selected for this work: C. S. Martin, of J. S. Martin & Co., F. B. Swift, of A. N. Grant & Co., and D. W. Whitmore, of D. W. Whitmore & Co. We give the average of the scores in the following table:

TABLE IV.—SHOWING RESULTS OF SCORING OF CHEESE.

No. of lot of cheese.	Date of examination.	Temperature of curing room.	Flavor.	Texture.	Color.	Finish.	Total score.	Remarks.
I.	Oct. 6, 1902.	.....	48	24	15	10	97	
"	Dec. 15, 1902.	40°F.	48	24	15	10	97	
"	" " " .	50°F.	46.5	23	15	10	94.5	
"	" " " .	60°F.	46	22	15	10	93	
"	Feb. 13, 1903.	40°F.	46.7	33.3	15	10	95	
"	" " " .	50°F.	44.3	23	14.7	10	92	
"	" " " .	60°F.	42.7	22	14.3	10	89	
"	Apr. 10, 1903.	40°F.	46.3	23	14.7	10	94	Flavor, not perfectly clean.
"	" " " .	50°F.	44.7	22.7	14.6	10	92	Flavor, tainted.
"	June 1, 1903.	40°F.	48	24.7	15	10	97.7	Clean flavor and silky texture.
II.	Oct. 6, 1902.	.....	48	24	15	10	97	
"	Dec. 15, 1902.	40°F.	48	23.5	15	10	96.5	
"	" " " .	50°F.	48	23	15	10	96.0	
"	" " " .	60°F.	47	22.5	15	10	94.5	
"	Feb. 13, 1903.	40°F.	46	22	15	10	93	
"	" " " .	50°F.	45	22	15	10	92	
"	" " " .	60°F.	44	22	15	10	91	
"	Apr. 10, 1903.	40°F.	45.7	22.3	15	10	93	Flavor, not perfectly clean.
"	" " " .	50°F.	43.7	22.3	14.7	10	90.7	Flavor, tainted.
" ...	June 1, 1903.	40°F.	46	23	15	10	94	Flavor, flat; texture smooth and silky.

TABLE IV.—(*Continued*).

No. of lot of cheese.	Date of examination.	Temperature of curing room.	Flavor.	Texture.	Color.	Finish.	Total score.	Remarks.
III.....	Oct. 7, 1902.	......	48	24	15	10	97	
"	Dec. 15, 1902.	40° F.	48.5	24	15	10	97.5	
"	" " "	50° F.	48	24	15	10	97	
"	" " "	60° F.	46.5	23	15	10	94.5	
"	Feb. 13, 1903.	40° F.	47.7	23.7	15	10	96.4	Flavor, clean; texture, wax-like.
"	" " "	50° F.	47.7	24.0	15	10	96.7	
"	" " "	60° F.	45.3	23.3	14.8	10	94.4	
"	Apr. 10, 1903.	40° F.	47.7	24	15	10	96.7	Flavor, slightly bitter.
"	" " "	50° F.	46.7	23.7	15	10	95.4	
"	June 1, 1903.	40° F.	47	24	15	10	96.0	Flavor, clean; texture, smooth and silky.
IV. A..	Oct. 8, 1902.	......	47	23	14	10	94.0	Rather acid and of imperfect color.
" "	Dec. 15, 1902.	40° F.	47.5	23.5	14	10	95.0	
" "	" " "	50° F.	46.5	22.5	13.5	10	92.5	
" "	" " "	60° F.	44.5	22	13.5	10	90.0	
" "	Feb. 13, 1903.	40° F.	44.7	22.7	13.3	10	90.7	
" "	" " "	50° F.	42.3	22	12.3	10	86.6	
" "	" " "	60° F.	41.7	21.3	12	10	85.0	
" "	Apr. 10, 1903.	40° F.	46	23	14.7	10	93.7	Flavor, acid; *texture, stiff.*
" "	" " "	50° F.	43.3	22	13	10	88.3	Flavor, acid and not clean; texture, harsh; color, imperfect.
" "	June 1, 1903.	40° F.	46	23	12.7	10	91.7	Flavor, clean; texture, smooth and silky; color, light.
IV. B..	Oct. 8, 1902.	......	48	23	15	10	96.0	
" "	Dec. 15, 1902.	40° F.	48	23.5	15	10	96.5	
" "	" " "	50° F.	47.5	23.5	15	10	96.0	
" "	" " "	60° F.	46.5	22.5	15	10	94.0	
" "	Feb. 13, 1903.	40° F.	47.3	23.7	15	10	96.0	
" "	" " "	50° F.	45	22	15	10	92.0	
" "	" " "	60° F.	44	22	15	10	91.0	
" "	Apr. 10, 1903.	40° F.	46.3	24.3	15	10	95.6	
" "	" " "	50° E.	46.3	24	14.7	10	95.0	
" "	June 1, 1903.	60° F.	46.7	23.3	15	10	95.0	Flavor, clean; texture, wax-like.
V.	Oct. 13, 1902.	......	46	23	15	10	94	
"	Dec. 15, 1902.	40° F.	46.5	23.5	15	10	95	
"	" " "	50° F.	45	22.5	15	10	92.5	
"	" " "	60° F.	40.5	20.5	15	10	86	

TABLE IV.—(*Concluded*).

No. of lot of cheese.	Date of examination.	Temperature of curing room.	Flavor.	Texture.	Color.	Finish.	Total score.	Remarks.
V.	Feb. 13, 1903.	40° F.	45.3	21.3	14.7	10	91.7	
"	" " " .	50° F.	43.7	20.3	14.7	10	88.7	
"	" " " .	60° F.	43	20	14.7	10	87.7	
"	Apr. 10, 1903.	40° F.	45.3	22	14.7	10	92.0	Flavor and texture, imperfect.
"	" " " .	50° F.	44	21.7	14.3	10	90.0	Slightly bitter and of weak texture.
"	June 1, 1903..	40° F.	46	22.7	15	10	93.7	Flavor, clean; texture, smooth and pasty.
VI. An.	Dec. 15, 1902.	40° F.	49	24	15	10	98.0	
" " .	" " " .	50° F.	48.5	23.5	15	10	97.0	
" " .	" " " .	60° F.	48	23.5	15	10	96.5	
" " .	Feb. 13, 1903.	40° F.	48	24	15	10	97.0	
" " .	" " " .	50° F.	48	24	15	10	97.0	
" " .	" " " .	60° F.	45.3	23	15	10	93.3	
" " .	Apr. 10, 1903.	40° F.	48	24	15	10	97.0	
" " .	" " " .	50° F.	48	24	15	10	97.0	
" " .	June 1, 1903..	40° F.	47.7	24.3	15	10	97.0	Surface covered with mold.
VI. Ap	Feb. 13, 1903.	40° F.	48	24	15	10	97.0	
" " .	" " " .	50° F.	48	24	15	10	97.0	
" " .	" " " .	60° F.	46.3	23.3	15	10	94.3	
" " .	Apr. 10, 1903.	40° F.	48.3	24	15	10	97.3	
" " .	" " " .	50° F.	48	24	15	10	97.0	
" " .	June 1, 1903..	40° F.	48.7	24.3	15	10	98.0	Condition, practically perfect; surface, bright and clean.
VI. Bn.	Feb. 13, 1903.	40° F.	48	24	15	10	97.0	
" "	" " "	50° F.	48	24	15	10	97 0	
" "	" " "	60° F.	44.7	22.7	14.3	10	91.7	
" "	Apr. 10, 1903.	40° F.	48	24	15	10	97.0	
" "	" " "	50° F.	47	24	15	10	96 0	
" "	June 1, 1903..	40° F.	47.7	24.3	15	10	97.0	Surface covered with mold.
VI. Bp.	Feb. 13, 1903.	40° F.	48	24	15	10	97.0	
" "	" " "	50° F.	48	24	15	10	97.0	
" "	" " "	60° F.	45.7	23	15	10	93.7	
" "	Apr. 10, 1903.	40° F.	48	24	15	10	97.0	
" "	" " "	50° F.	47	24	15	10	96 0	
" "	June 1, 1903..	40° F.	48.7	24.3	15	10	98.0	Condition, practically perfect; surface, bright and clean.

From the data embodied in the preceding table, we are able to present the following statement as a summary of the results:—

(1) Almost without exception the cheese cured at lower temperatures was superior in quality to that cured at higher temperatures. Cheese cured at 40° F. usually scored higher than that cured at 50° F., and the cheese cured at 50° F. scored higher in every instance than that cured at 60° F. Averaging all our results, we have the following general scores for the different temperatures: At 40° F., 95.7; at 50° F., 94.2; at 60° F., 91.7. From these figures we see that the cheese deteriorated considerably more at 60° F. as compared with 50° F., than it did at 50° F. as compared with 40° F. The difference of scores is 1.5 in favor of 40° F., as compared with 50° F., and 2.5 in favor of 50° F. as compared with 60° F. In other words, the higher the temperature, the greater is the relative deterioration of cheese in quality for each degree of temperature.

(2) The difference in quality fell mostly on the flavor and texture. Averaging all our figures, we have the following results:

	40° F.	*50° F.*	*60° F.*
Flavor	47.4	46 4	44 8
Texture	23 4	23.0	22.2

Here, also, we see that the difference is greater between 60° F. and 50° F. than between 50° F. and 40° F. in the direction of poorer quality.

(3) At any given time the cheese cured at 40° F. was usually better in quality than that at 50° F., and that at 50° F. was better than that at 60° F. The longer the time of curing, the greater was the difference in favor of the lower temperatures. The following tabulated averages of the results illustrate these statements:

Age of cheese.	Score at 40° F.	50° F.	60° F.
10 weeks	96 3	94.7	92
20 "	93.8	91.5	89 7
28 "	94.2	91 9	....
35 "	95.3	....	....

The cheeses cured at 60° F. showed such deterioration in quality at the end of 20 weeks that they were sold. While the cheeses cured at 40° F. and 50° F. showed some deterioration in quality at 20 weeks, they scored higher at 28 weeks than at 20 weeks. The cheese kept at 40° F. showed its highest score at

35 weeks in several cases. The higher score was always in favor of the lower temperature by several points.

(4) The effect of covering cheese with paraffin was in several cases to improve the quality as compared with cheese not so covered. The difference was more marked at 60° F. than at lower temperatures. The cheeses covered with paraffin and cured at 40° F. showed their highest score at the end of 35 weeks.

		40° F.	50° F.	60° F.
Cheese normal (An)	20 weeks old.	97	97	93.3
" " (Bn)	" " "	97	97	91.7
Cheese covered with paraffin (Ap)	" " "	97	97	94.3
" " " " (Bp)	" " "	97	97	93.7
Cheese normal (An)	28 weeks old.	97	97	....
" " (Bn)	" " "	97	96	....
Cheese covered with paraffin (Ap)	" " "	97.3	97	....
" " " " (Bp)	" " "	97	96	....
Cheese normal (An and Bn)	35 weeks old.	97	....	....
Cheese covered with paraffin (Ap and Bp)	" " "	98	....	....

SOME PRACTICAL APPLICATIONS.

From the data presented in the foregoing pages, we have seen that the use of low temperatures in curing cheese shows two prominent results, (1) reduction of loss of weight and (2) improvement of commercial quality. Any reduction of loss of weight or any improvement in quality means an increase in the amount of money that can be realized in the sale of the cheese. It is a matter of practical interest and importance to consider in some detail what specific increased or decreased market values were found for the cheese under the different conditions of experiment.

ECONOMY IN REDUCING LOSS OF MOISTURE.

We have seen that the loss of moisture in curing cheese can be reduced by using a lower temperature or by covering cheese with a thin coating of paraffin or by a combination of these two conditions.

Increased amount of cheese resulting from using low temperatures.—Taking the longest period of time for which we were able to compare the results at the different temperatures employed, 20 weeks, we found that the cheese cured at 40° F. had lost, on an average, 3.8 pounds for 100 pounds of cheese; the cheese at 50° F. had lost 4.8 pounds; and that at 60° F., 7.8 pounds. For 100

pounds of cheese originally placed in the curing-rooms at the different temperatures, we had for sale at the end of 20 weeks 96.2 pounds of cheese cured at 40° F., 95.2 pounds at 50° F., and 92.2 pounds at 60° F.

Assuming that the cheese sells at a uniform price of 10 cents a pound, we should have receipts from our original 100 pounds of each of the different cheeses as follows:

Cheeses cured at 40° F.	$9 62
Cheeses cured at 50° F.	9 52
Cheeses cured at 60° F.	9 22

Under these conditions, the receipts from the cheese kept at 40° F. are 10 cents a hundred more than for that kept at 50° F. and 40 cents more than for that kept at 60° F. As we shall point out later, the differences are really greater than this.

Increased amount of cheese resulting from covering cheese with a coating of paraffin.—At the end of 17 weeks, cheese covered with paraffin had lost only 0.3 pound for 100 pounds of cheese originally placed in storage at 40° F., 0.5 pound at 50° F. and 1.4 pounds at 60° F. The saving thus effected, based on the uniform price of cheese at 10 cents a pound, would average about 35 cents for 100 pounds of cheese cured at 40° F., 43 cents at 50° F., and 64 cents at 60° F.; or, comparing cheese kept at 40° F., covered with paraffin, with cheese kept at 60° F. not so covered, there would be a difference of about 75 cents a hundred in favor of the paraffined cheese.

The cost of covering cheese with paraffin is slight. Conveniences for this work can be obtained from manufacturers of dairy supplies.

INCREASED MARKET VALUE RESULTING FROM IMPROVEMENT IN QUALITY OF CHEESE CURED AT LOW TEMPERATURES.

We have already studied the results of the scores furnished by the experts who examined the cheeses from time to time. They were requested also to place upon the different lots of cheese a commercial valuation, based upon the results of their scoring. Below we present these commercial valuations in tabulated form:

TABLE V. — SHOWING MARKET VALUE OF ONE POUND OF CHEESE.

Date of examination.	Temperature of curing room.	Lot I.	Lot II.	Lot III. A & B	Lot IV.		Lot V.	Lot VI.			
					A	B		An.	Ap.	Bn.	Bp.
1902.		*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
Dec. 15.....	40° F.	13	13	13	13	13	13	13¾	13¾	13¾	13¾
" ".....	50° F.	12¾	13	13	12½	13	12½	13¾	13¾	13¾	13¾
" ".....	60° F.	12½	12¾	12¾	12	12¾	11¾	13¾	13¾	13¾	13¾
1903.											
Feb. 13.....	40° F.	13	12½	13	12	13	12¼	14¼	14¼	14¼	14¼
" ".....	50° F.	12¼	12¼	13	11¾	12¼	12	14¼	14¼	14¼	14¼
" ".....	60° F.	12	12¼	12¾	11¾	12¼	11¾	13½	13¾	13¼	13½
Apr. 9.....	40° F.	12¾	12½	13	12½	13	12½	14¾	14¾	14¾	14¾
" ".....	50° F.	12¼	12¼	13	12	13	12¼	14½	14¾	14½	14¾
June 1.....	40° F.	....	....	....	....	....	....	14½	14½	14¾	14¾

In studying the data embodied in Table V, we notice the following points:

(1) In the case of lots I to V, the market value of the cheese cured at 40° F. was greater in most cases than that cured at 50° F. and, in every case, greater than that cured at 60° F. In most cases, the cheese cured at 50° F. had a higher market value than that cured at 60° F. These statements hold good for the 20 weeks during which the cheeses were kept at the three different temperatures. If the cheeses cured at 60° F. had been kept for a longer period, they would have shown serious decrease in value.

In the case of Lot VI, the market value was the same for all temperatures on December 15th, when the cheese was about 8 weeks old. Two months later, there was no difference at the temperature of 40° F. and 50° F., but the cheese kept at 60° F. had a lower market value than the cheese kept at the lower temperatures. In April, when the cheese was about 25 weeks old, there was a little difference in favor of the lower temperature.

(2) In comparing the cheeses covered with paraffin (Lot VI Ap and Bp) with those left in the usual condition (An and Bn), there was no difference in their market value during the first 17 weeks at the temperatures 40° F. and 50° F. At 60° F. at the end of 17 weeks, the cheeses covered with paraffin were valued a quarter of a cent a pound more than the unparaffined ones. When the cheese kept at 40° F. was 25 and 32 weeks old, there

was no difference in market value between the paraffined cheeses and those not paraffined; but, in the cheeses kept at 50° F. there was, at the end of 25 weeks, an increased market value of a quarter of a cent a pound in favor of the paraffined cheese. It appears from these results that, in cheese covered with paraffin, the results are more marked at higher temperatures than at lower temperatures in favor of the paraffined cheese, but even then only after the first few months of ripening. The chief value of paraffining cheese appears to be in preventing loss of moisture and in keeping the surface free from molds.

(3) If we average the results obtained with the different lots we have the following figures:

Date of examination.	Temperature of curing.	Market value per pound.
Dec. 15, 1902.	40° F.	13.300 cents.
" " "	50° F.	13.175 "
" " "	60° F.	12.950 "
Feb. 13, 1903.	40° F.	13.275 "
" " "	50° F.	13.050 "
" " "	60° F.	12.675 "
Apr. 9, 1903.	40° F.	13 525 "
" " "	50° F.	13.325 "

At the end of 10 weeks, the cheese cured at 40° F. was worth 12½ cents more a hundred pounds than the cheese cured at 50° F., and 35 cents more than that cured at 60° F. The cheese cured at 50° F. was worth 22½ cents more than that cured at 60° F.

At the end of 20 weeks, the cheese cured at 40° F. was worth 22½ cents more a hundred pounds than that cured at 50° F., and 60 cents more than that cured at 60° F., while that cured at 50° F. was worth 37½ cents more than that cured at 60° F.

At the end of 28 weeks, the cheese cured at 40° F. was worth 20 cents more a hundred pounds than that cured at 50° F.

INCREASED RECEIPTS FROM CHEESE CURED AT LOW TEMPERATURE AND COVERED WITH PARAFFIN.

We have seen that the curing of cheese at low temperatures has the effect of (1) preventing loss of moisture and (2) increasing the market value of the cheese. Therefore, we not only have more cheese to sell but can sell it at a higher price. Taking cheese 20 weeks old as a basis for comparison, we know how much weight is lost at different temperatures and also the difference in market price. From these figures, we can prepare the following tabulated statement:

Temperature of curing.	Cured cheese equivalent to 100 pounds of green cheese.	Market price of one pound of cheese.	Receipts from cheese.
	Lbs.	*Cents.*	
40° F.	96.2	13.275	$12 77
50° F.	95.2	13.050	12.42
60° F.	92.2	12.675	11.69

These figures indicate that, from 100 pounds of cheese put into the curing-room, we were able to realize from that cured at 40° F. 35 cents more than from cheese cured at 50° F., and $1.08 more than from that cured at 60° F. From the cheese cured at 50° F., we received 73 cents more a hundred pounds than from that cured at 60° F.

If we compare our 1esults obtained with cheese covered with paraffin with those given by cheese not so covered, we have the following tabulated statement:

Temperature of curing room.	Cured cheese equivalent to 100 pounds of green cheese.		Market price of one pound of cheese.		Receipts from cheese.	
	Paraffined.	Not paraffined.	Paraffined.	Not paraffined.	Paraffined.	Unparaffined.
	Lbs.	*Lbs.*	*Cents.*	*Cents.*		
40° F.	99.7	96.2	14.25	14.25	$14.21	$13.70
50° "	99.5	95.2	14 25	14.25	14.19	13.56
60° "	98.6	92.2	13.75	13.50	13.56	12.45

At 40° F. the difference in favor of the paraffined cheese is 51 cents for 100 pounds of cheese originally placed in the curing-room; at 50° F. the difference in 63 cents; and at 60° F. $1.11. Covering cheese with paraffin results in greater saving at higher than at lower temperatures.

Comparing paraffined cheese cured at 40° F. with unparaffined cheese cured at 60° F., we find a difference of $1.76 for 100 pounds of cheese in favor of the paraffined cheese and the lower temperature.

ADVANTAGES OF CURING CHEESE AT LOW TEMPERATURES.

Briefly summarized, the advantages of curing cheese at low temperatures are the following:

(1) The loss of moisture is less at low temperatures, and therefore there is more cheese to sell.

(2) The commercial quality of cheese cured at low temperatures is better and this results in giving the cheese a higher market value.

(3) Cheese can be held a long time at low temperatures without impairment of quality.

(4) By utilizing the combination of paraffining cheese and curing it at low temperatures, the greatest economy can be effected.

RESULTS OF CHEMICAL ANALYSIS OF CHEESE.

The analytical data were obtained by the methods published in Bulletin No. 215, except that the paranuclein, caseoses and peptones were not separated from one another, their combined amount being obtained by difference.

TABLE VI.—RESULTS OF CHEMICAL ANALYSIS.

Lot of cheese.	Temp. of curing room.	Date of analysis.	Water in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—				
				Paracasein-monolactate.	Water-soluble nitrogen.	Paranuclein, caseoses and peptones.	Amides.	Ammonia.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
I. ..	.....	Oct. 8....	34 20	60 42	14.35	9.72	4.63	0
" ..	40°F.	Dec. 23..	34.56	42.53	21.95	12.00	8.37	1.58
" ..	50°F.	" " ..	33.60	36 88	25.83	14 55	9.33	1.95
" ..	60°F.	" " ..	34 61	37.72	30.14	14.73	13.62	1.79
" ..	40°F.	Feb. 18..	31.90	43.82	24.72	17.98	4.94	1.80
" ..	50°F.	" " ..	30.40	35.78	31.34	17.11	11.56	2.67
" ..	60°F.	" " ..	30.46	31.27	35 92	16.85	15.52	3.55
" ..	40°F.	Apr. 13..	33.79	42 70	28.32	16.41	9 44	3.47
" ..	50°F.	" " ..	33 63	27.60	36.65	15.68	17.00	3.97
" ..	40°F.	June 3...	34.38	18.65	30.57	15.65	11.92	3.10
II. ..	.....	Oct. 8...	34 43	40.70	17.47	11.72	5.06	0.69
" ..	40°F.	Dec. 23..	34.08	35.78	19.56	10.23	7.33	2.00
" ..	50°F.	" " ..	34.20	29.26	28.35	17.70	8.10	2.49
" ..	60°F.	" " ..	34.57	28.51	27 86	15.14	10 31	2.41
" ..	40°F.	Feb. 18..	32.40	34 79	22.59	15.68	4 84	2.07
" ..	50°F.	" " ..	31 20	26.02	31 90	20.82	8.37	2.71
" ..	60°F.	" " ..	30.56	22 52	34.00	19.65	10.82	3.53
" ..	40°F.	Apr. 13..	31.86	42.95	22.03	12.78	6.83	2.42
" ..	50°F.	" " ..	31.76	20.48	32.76	18.75	11.21	2.80
" ..	40°F.	June 5...	32.09	46.07	25.13	15.97	7 33	1.83

TABLE VI.—(*Continued.*)

Lot of cheese.	Temp. of curing room.	Date of analysis.	Water in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—				
				Paracasein-monolactate.	Water-soluble nitrogen.	Paranuclein, caseoses and peptones.	Amides.	Ammonia.
III. A.	.....	Oct. 8..	35.44	58 13	13.04	9.61	3.43	0
" B.	.....	" " ..	35.40	57.05	12.93	9.00	3.93	0
" A.	40°F.	Dec. 21..	36.25	50.23	22.40	14.03	7.02	1.36
" B.	"	" " ..	36.75	46.36	21.55	12.93	7.03	1.59
" A.	50°F.	" " ..	36.04	43 43	26 95	17 82	7.35	1.78
" B.	"	" " ..	35.33	37.36	28.57	18.68	8.13	1.76
" A.	60°F.	" " ..	34.63	36.69	31.77	21 03	8.95	1.79
" B.	"	" " ..	36.40	39.24	28.70	17 49	9.19	2.02
" A.	40°F.	Feb. 16..	36.60	50.00	25 95	18.57	5.24	2.14
" B.	"	" " ..	36.80	44.98	25.35	19.18	4.57	1.60
" A.	50°F.	" " ..	35.61	35.83	30.61	21 55	7.48	1.59
" B.	"	" " ..	35.57	34.69	33.56	22 92	8.16	2.49
" A.	60°F.	" " ..	34.47	31.46	36.18	22.92	10.34	2.92
" B.	"	" " ..	34.34	28.51	36.19	24.13	9 65	2 41
" A.	40°F.	Apr. 13..	35 82	35 59	29.05	19.14	7.21	2.70
" B.	"	" " ..	34 14	33 41	30.96	20.49	8.02	2.45
" A.	50°F.	" " ..	35 18	30.44	31 53	18.69	10.00	2 83
" B.	"	" " ..	34.96	33.78	31,99	20.13	8.95	2.91
" A.	40°F.	June 3..	35.01	26.78	29·34	18.88	8.16	2.30
" B.	"	" 5..	34.40	42.85	26·76	17.59	6.37	2.80
IV. A.	40°F.	Dec. 18..	39 34	48.19	21.37	13.41	7.05	0.91
" B.	"	" " ..	37 29	43.78	20.28	12.00	7.14	1.15
" A.	50°F.	" " ..	37.40	42.96	26.49	14.55	9.55	2.39
" B.	"	" " ..	37.14	35.04	27.34	12 62	12.85	1.87
" A.	60°F.	" " ..	37.44	47.73	25.69	15.68	7.96	2.05
" B.	"	" " ..	36 44	26.73	30.51	15.81	12.25	2.45
" A.	40°F.	Feb. 18..	39.17	38 98	24.59	16.01	6.96	1.62
" B.	"	" " ..	34.00	45.42	22.02	15.82	4.59	1.61
" A.	50°F.	" " ..	38.61	37 18	31.18	19.63	8.78	2.77
" B.	"	" " ..	34 70	35.49	33 64	20.74	9 91	2.99
" A.	60°F.	" " ..	36 98	32 48	38.83	16.48	17.88	4.47
" B.	"	" " ..	29 62	33 11	36.47	15.89	17.00	3.58
" A.	40°F.	Apr. 13..	36.04	40 62	25.39	17.22	5.52	2.65
" B.	"	" " ..	35.71	37.09	24.06	12.36	8 83	2.87
" A.	50°F.	" " ..	36.77	35.71	35.00	15.24	15 24	4.52
" B.	"	" " ..	34.83	33.33	32.00	14.00	14.22	3.78
" A.	40°F.	June 1..	37.27	30.95	27.12	17.80	6.85	2.47
" B.	"	" " ..	36.20	39.15	29 37	14.82	11.64	2.91
V....	"	Dec. 18..	38 48	49 05	22.06	14.70	6.13	1.23
" ...	50°F.	" " ..	38.46	41.30	24.88	13 68	8.96	2.24
" ...	60°F.	" " ..	37.58	27.96	27.98	16 57	9.09	2.33
" ...	40°F.	Feb. 16..	38 07	50 25	25.63	18.10	6.28	1.25
" ...	50°F.	" " ..	37.99	37.98	32.69	19.71	9.86	3.12
" ...	60°F.	" " ..	36 54	35 80	36 99	21.24	12.41	3.34
" ...	40°F.	Apr. 15..	35.94	48.17	25 69	16.52	5.96	3.21
" ...	50°F.	" " ..	37 55	33.18	37 21	18.49	14.22	4.50
" ...	40°F.	June 5..	36.16	34.65	29.10	18.52	8.20	2.38

TABLE VI. — (*Concluded.*)

Lot of cheese.	Temp. of curing room.	Date of analysis.	Water in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—				
				Paracasein-monolactate.	Water-soluble nitrogen.	Paranuclein, caseoses and peptones.	Amides.	Ammonia.
VI. An.	.....	Oct. 29..	34 97	62.08	12.87	9.48	3.39	0
" Ap.	.....	" " ..	35 20	66.14	15.02	11.21	3.81	0
" An.	40°F.	Dec. 17..	35.05	65.34	15.78	9.56	6 22	0
" Ap.	"	" " ..	34.86	50.32	15.30	8.30	5.99	1 00
" An.	50°F.	" " ..	34.82	53.96	22.03	12.66	8.37	1.00
" Ap.	"	" " ..	34.37	58 51	25.17	15.65	8.16	1 36
" An.	60°F.	" " ..	34.76	51.66	25.39	16 77	7 29	1 33
" Ap	"	" " ..	34.39	37.61	28.32	16.81	9 96	1 55
" An.	40°F.	Feb. 20..	35.08	56.76	25.90	16.67	7.43	1.80
" Ap.	50°F.	" " ..	34.15	58.94	20.31	14.73	4 91	0.67
" An.	"	" " ..	34 51	37.67	26.46	16 60	8.07	1 79
" Ap.	"	" " ..	33.35	36.51	32.66	22.46	8 39	1.81
" An.	60°F.	" " ..	32.16	30.50	34 43	19.39	12.42	2 62
" Ap.	"	" " ..	33 28	31.32	37.14	19.69	13.65	3 80
" An.	40°F.	Apr. 15..	35.06	44.56	25.00	16.09	7.17	1.74
" Ap.	"	" " ..	34.71	39.78	25.94	14 29	9.45	2.20
" Bn.	"	" " ..	34.12	35 32	27.82	17 66	7.95	2.21
" Bp.	"	" " ..	34 37	30.98	25.45	16.67	6.86	1.92
" An.	50°F.	" " ..	34.03	36.83	28 58	14.96	10.27	3 35
" Ap.	"	" " ..	34 02	35.01	31 39	15.53	13.13	2 63
" Bn.	"	" " ..	34.66	31.11	32.00	16 44	12 45	3.11
" Bp.	"	" " ..	34 42	24.34	32 75	17 04	12.61	3.10
" An.	40°F.	June 3..	33.80	46.75	26.00	13.50	10.00	2 50
" Ap.	"	" " ..	34 80	50.12	25.06	12 41	10.12	2.53
" Bn.	"	" " ..	33.59	44.70	24 50	13.02	9.18	2 30
" Bp.	"	" " ..	34 40	33.08	28.50	16.79	9 41	2 30

(1) *The process of cheese-ripening.*—When cheese ripens, the most prominent change taking place is in the nitrogen compounds. The casein of milk is changed by the action of rennet-enzymes into curd, chemically known as paracasein. In the process of cheese-making, lactic acid is formed and this unites with the paracasein, forming a compound known as paracasein monolactate.[1] It is this compound that imparts to cheese-curd the property of forming fine strings on a hot iron and it is the formation of this paracasein monolactate that accounts for the changes in appearance, plasticity and texture of cheese-curd during the process of cheddaring. Moreover, there is reason to believe that the changes that take place in the process of cheese-

(1) Bull. No. 214, N. Y. Agr. Exp. Sta. (1902.)

ripening start with and are dependent upon the presence of paracasein monolactate or some similar compound. Hence, from a chemical point of view, cheese-ripening consists mainly of the change of paracasein monolactate into other forms of nitrogen compounds, chief among which in the order of their formation are paranuclein, caseoses, peptones, amido compounds and ammonia. These compounds, formed from paracasein monolactate, are readily soluble in water, while paracasein monolactate is not. Hence, in ripening cheese we have larger amounts of substances that are soluble and smaller amounts of substances that are insoluble than in green cheese. Ripening cheese is believed, for this reason, to be more readily digestible than green cheese. The amount of soluble nitrogen compounds is used as a measure of the extent of cheese-ripening.

This present investigation offers an opportunity of studying the chemical results of cheese-ripening under different conditions of temperature and with a number of different types of cheddar cheese under commercial conditions.

(2) *Moisture in cheese.*—Before taking up a study of the nitrogen compounds of the cheeses under investigation, we will call attention to the amount of moisture in the cheese.

In the case of Lots I, II, III and IV, in which the moisture was determined when the cheese was placed in cold storage, we found the moisture content varying from 34.20 to 35.44 per ct.; this may be regarded as a comparatively small variation. In Lots IV and V, the moisture must have been above 40 per ct. at the time the cheese was placed in cold storage, because 10 weeks later, when we made the first analysis, the moisture was about 39 per ct. The results of moisture determination show a gradual decrease in moisture as the cheese becomes older, as indicated by the following averages:

	Percentage of moisture in cheese.		
When put in cold storage.... 36.50 per ct.	*At 40° F.*	*At 50° F.*	*At 60° F.*
After being in storage 10 wks.	36.30	35.70	35.65
" " " " 20 "	35.35	34.66	34.26

The decrease of moisture is greater with increase of temperature, a point which has been dwelt upon in connection with loss of weight.

(3) *Amount of paracasein monolactate in cheese.*—The amount of paracasein monolactate formed in the different cheeses when 1 and 2 weeks old, varied from 40.70 to 66.14 per ct. of the nitrogen in the cheese and averaged 57.49 per ct. The amount decreased as the cheese aged, and more rapidly at higher than at lower temperatures, as shown by the following general averages:

Age of cheese.	Percentage of nitrogen in cheese in form of paracasein monolactate.		
	40° F.	50° F.	60° F.
1 week	57.49	57.49	57 49
10 weeks	47.94	42 08	37.09
20 "	47 10	35.24	30.77
28 "	40.54	31.82	....
35 "	36 36	....	....

This diminution of paracasein monolactate is undoubtedly due to its conversion into water-soluble nitrogen compounds.

(4) *Amount of water-soluble nitrogen compounds in cheese.*—While the amount of water-soluble compounds of nitrogen in cheese is not a guide in respect to the detailed chemical changes taking place in ripening cheese, it serves as a general indication of the extent and rapidity of those changes. The data below, representing averages of our results, show that the amount of water-soluble nitrogen increases with increase of temperature and with lapse of time.

Age of cheese.	Percentage of nitrogen in cheese in form of water-soluble compounds.		
	40°F.	50°F.	60°F.
1 week	14 55	14.55	14.55
10 weeks	20 03	25 18	28 48
20 "	24.12	31.56	36.24
28 "	26.27	33.00	....
35 "	27.64	....	....

(5) *Amount of amido compounds in cheese.*—The amido compounds of cheese are of interest because it is possible that among these compounds we are to look for the substance or substances responsible for cheese flavors. Little or no cheese flavor appears in cheese until amido compound are formed. Their amount

increases with temperature and with lapse of time, as shown by the following averages:

Age of cheese.	Per ct. of nitrogen in form of amido compounds.		
	40°F.	50°F.	60°F.
1 week	4.06	4 06	4 06
10 weeks	6.92	8.98	9.85
20 "	5.53	8.95	13.30
28 "	7.60	12.70	....
35 "	9.00	....	....

(6) *Amount of ammonia in cheese.*—The formation of ammonia in cheese may possibly be associated also with the development of cheese flavor. No ammonia is found in fresh cheese. It begins to be formed in appreciable quantities in about 4 weeks and increases with the age of the cheese. Its amount is greater at higher than at lower temperatures. The following averages give a good idea of the amount found in cheese under the conditions indicated:

	Per ct. of nitrogen in cheese in form of ammonia.		
	40°F.	50°F.	60°F.
1 week	0	0	0
10 weeks	1.20	1.87	1.97
20 weeks	1 62	2.44	3.36
28 weeks	2 52	3 48	....

CONDITIONS AFFECTING CHEMICAL CHANGES IN CHEESE-RIPENING.*

L. L. VAN SLYKE AND E. B. HART.

SUMMARY.

1. Object.—This bulletin contains the results of study relating to some of the more prominent conditions that influence the chemical changes taking place in cheese during the ripening process.

2. Influence of Time.—The amount of soluble nitrogen compounds increases as cheese ages. The rate of formation of these compounds is more rapid in the early stages of ripening, about two-thirds being formed during the first 3 months, and over 90 per ct. in the first 9 months, of an 18-month period of study.

3. Effect of Different Temperatures.—Soluble nitrogen compounds increase in cheese-ripening quite closely in proportion to increase of temperature. Between the limits of 32° F. and 70° F., there was an increase of 0.5 per ct. of soluble nitrogen compounds for an increase of one degree of temperature. The amido compounds and ammonia were more abundantly formed and they steadily accumulated in cheese cured at higher temperatures.

4. Influence of Moisture Content of Cheese.—Cheese containing more moisture, other conditions being uniform, generally contains larger amounts of soluble nitrogen compounds, especially after the early stages of ripening.

5. Influence of Size of Cheese.—Cheeses of large size usually form soluble nitrogen compounds more rapidly than smaller cheeses under

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the same conditions, because large cheeses have a higher water content after the early period of ripening.

6. Effect of Salt.—Cheese containing more salt forms soluble nitrogen compounds more slowly than cheese containing less salt. This appears to be due, in part, to the direct action of salt in retarding the activity of one or more of the ripening agents, and, in part, to the tendency of the salt to reduce the moisture content of the cheese.

7. Effect of Different Amounts of Rennet.—The use of increased amounts of rennet-extract in cheese-making, other conditions being uniform, results in producing increased quantities of soluble nitrogen compounds in a given period of time, especially such compounds as paranuclein, caseoses and peptones.

8. Influence of Acid.—Acid is necessary for the formation of paracasein monolactate, from which soluble nitrogen compounds appear to be formed in normal cheese-ripening; but the exact relation of varying quantities of acid to the chemical changes of the ripening process has not yet been fully studied.

9. Transient and Cumulative Products of Cheese-Ripening.—Paracasein, caseoses and peptones usually vary within small limits and do not usually accumulate in cheese in increasing quantities but after a while decrease, while amides and ammonia are found to accumulate continuously during the normal ripening process. Low temperatures favor some accumulation of the transient products, while high temperatures favor the more rapid accumulation of amides and ammonia.

10. Influence of Products of Proteolysis on Cheese-Ripening.—The accumulation of soluble nitrogen compounds in cheese appears to diminish the action of the agents causing the changes, so that cheese ripens less rapidly after the first period.

11. Why Moisture Affects Cheese-Ripening Process.—An increased moisture content in cheese favors more active chemical change for two reasons: (1) Moisture in itself favors the activity

of ripening ferments; (2) the presence of increased amounts of moisture serves to dilute the fermentation products that accumulate.

12. Some Practical Considerations.—The conditions of the manufacture of cheese and of ripening determine the rapidity and extent to which chemical changes take place in the nitrogen compounds during ripening. The following conditions promote more rapid change: (1) Increase of temperature in ripening; (2) larger amount of rennet; (3) higher moisture content of cheese; (4) decreased amount of salt; (5) large size of cheese; and (6) moderate amount of acid. Cheese made and handled so as to ripen slowly is of higher commercial value.

INTRODUCTION.

The object of this bulletin is to present the results of our study relating to some of the more prominent conditions that influence the chemical changes taking place in the nitrogen compounds of cheese during the ripening process. It is well known that, during the cheese-making process, chemical changes soon begin in the freshly coagulated curd or paracasein formed when milk-casein is acted upon by rennet. The same cheese examined at intervals is found to show quite marked variations in the character of its nitrogen compounds. Cheeses made from the same milk under the same conditions of manufacture and subjected to different conditions during the ripening process show a difference in chemical composition. Cheeses manufactured under different conditions and ripened under uniform conditions may vary in the character of their nitrogen compounds. It has seemed to us desirable that a somewhat comprehensive study should be made of the changes actually found in the nitrogen compounds of cheese, using in the work only cheeses made and ripened under known, controlled conditions. The results presented in this bulletin by no means exhaust the subject, our intention being to study first only some of the more prominent factors, such as time, temperature, moisture, salt, rennet, acid, etc.

The chief proteid of curd, freshly coagulated by rennet, is, under usual conditions, a compound called paracasein, in some respects resembling milk-casein, in other respects differing from it in a marked degree. The exact chemical relation of these two compounds has not yet been learned. In the usual methods of cheese-making, the milk-sugar, acted on by certain organisms, begins to form lactic acid early in the process and this acid, as rapidly as formed, combines chemically with paracasein to form a compound called paracasein monolactate. Many of the peculiar properties of curd are believed to be due to the presence of this paracasein monolactate, such as the ability to form fine strings on a hot iron, the changes in appearance, plasticity and texture and, perhaps, the shrinking. It is also probable that paracasein monolactate forms the real starting point of cheese-ripening or, stated

another way, that we must have paracasein monolactate present before we can have formed such compounds as caseoses, peptones and amides. Starting with the casein of milk, we have in cheese-curd and ripening cheese the following nitrogen compounds formed in something like the following order: paracasein, paracasein monolactate, paranuclein, caseoses, peptones, amido compounds and ammonia compounds. The amounts of these different compounds and classes of compounds and their relations to one another we shall study in some detail in the following pages.

In the manufacture of the cheeses used in the work, we had the skilful services of Mr. Geo. A. Smith. The general plan was to follow the usual commercial methods employed in making cheddar cheese. Where there was any departure from normal methods, notice is called to it in connection with the discussion or the analytical tables contained in the Appendix. The cheeses were kept under known conditions during the curing process. From 4 to 8 cheeses were made at a time from each separate lot of milk, the amount of milk varying from 400 to 1200 pounds. The cheeses were made in two sizes, 10 and 30 pounds.

The chemical results obtained may be used to some extent as standards of reference, so far as they represent normal cheddar cheese under the conditions given.

THE RELATION OF TIME TO THE CHEESE-RIPENING PROCESS.

An examination of the detailed analyses given in the Appendix shows, in the case of every individual cheese, under all the conditions studied, that there is a progressive change, resulting in an increase of water-soluble nitrogen compounds as the cheese advances in age. As we shall point out later, the effect of time as a factor in cheese-ripening is modified by a variety of conditions. For purpose of illustration, we will here give averages of the results obtained under the various conditions employed. Each analysis represents averages of the results obtained with 24 different cheeses, and they exhibit more fully than any other data published within our knowledge the detailed chemical changes that occur in the nitrogen compounds of cheese during the process of ripening.

TABLE I.—SHOWING EFFECT OF TIME ON CHEESE-RIPENING.

AGE OF CHEESE.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—						
	Paracasein mono-lactate.	Water-soluble nitrogen com-pounds.	Para-nuclein.	Caseoses.	Peptones.	Amides.	Am-monia.
Months.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1½	20.18	21.44	2.06	3.15	3.84	9.88	1.56
3	27.26	30.98	4 45	4.56	4.65	14.36	2.45
6	27 55	36 15	3.57	4 92	4.22	19.96	3 52
9	24.14	43.45	4.02	4.59	3.56	26.53	4.74
12	19.04	44.75	3.52	4.16	3.95	28.38	5.41
18	12.65	47.25	3.40	3.88	2.57	30.46	6.62

The data embodied in this table suggest the following statements:

(1) The total amount of nitrogen in the form of water-soluble compounds increases as the cheese gains in age. This increase is not uniform, since it is more rapid in the early stages of ripening, gradually decreasing in rate with the increasing age of the cheese. Thus, calculating the average monthly increase of water-soluble nitrogen, we have for the first month and a half an average monthly increase of 15 pounds for 100 pounds of nitrogen in the cheese; for the period extending from 1½ to 3 months, an average monthly increase of 6.3 pounds; from 3 to 6 months, 2.1 pounds; from 6 to 9 months, 2.4 pounds; from 9 to 18 months, 0.3 pound. Stated in another way, of the total amount of water-soluble nitrogen compounds formed in the cheese during 18 months, 45.4 per ct. was formed in the first month and a half; 65.5 per ct. in the first 3 months; 76.5 per ct. in the first 6 months; and 92 per ct. in the first 9 months or one-half the entire period covered by the study.

(2) The nitrogen in the form of paracasein monolactate appears to increase for 6 months and then gradually decrease. However, these data are not calculated to show the variations of this compound to advantage, since we have learned from other work of ours that paracasein monolactate commonly appears at its maximum quantity in fresh cheese and is very largely changed into

other forms in the course of a few weeks, the rapidity of its appearance and disappearance being dependent upon such conditions as the acidity of the cheese, the temperature of the curing-room, etc.

(3) The nitrogen in the form of paranuclein reaches its highest quantity in about 3 months and then slowly decreases some but not to a great degree.

(4) The nitrogen in the form of caseoses appears to increase from the beginning, reaching its maximum in 3 to 6 months and then gradually decreasing some.

(5) The nitrogen in the form of peptones increases from the start, reaching its highest quantity in about 3 months, after which there is a slow decrease until after 12 months, when the decrease is more marked.

(6) The amido compounds increase with comparative rapidity during the early stages of ripening. The increase continued during the whole period of study but at a less rapid rate. Thus, the average monthly increase for the first period was 6.60 pounds for 100 pounds of nitrogen in cheese; for the second, 3 pounds; for the third, 1.87 pounds; for the fourth, 2.2 pounds; for the fifth, 0.62 pound; and for the sixth, 0.35 pound. Of the entire amount of amido compounds formed during 18 months, 87 per ct. was found at the end of 9 months; 65.5 per ct., at the end of 6 months; 47 per ct., at the end of 3 months; and about 33 per ct., at the end of one month and a half.

(7) The ammonia in cheese does not commonly reach an appreciable quantity until cheese is about a month old, after which it increases quite regularly. As in the case of the amido compounds, but in a much less marked degree, ammonia forms less slowly in the later than in the early stages of ripening. Considerably over half the ammonia was formed in the first 6 months, while about 70 per ct. of the entire amount found at the end of 18 months was formed in the first 9 months of ripening.

(8) Summarizing the statements made in connection with the data contained in Table I, we find that, other conditions being uniform, (a) the formation of water-soluble nitrogen compounds increases as cheese ages; (b) the rate of formation of water-solu-

ble nitrogen compounds is more rapid in the early stages of ripening, steadily diminishing with age; (c) about two-thirds of these compounds are formed in the first 3 months and over 90 per ct. in the first 9 months.

THE RELATION OF TEMPERATURE TO THE CHEESE-RIPENING PROCESS.

Instead of presenting all of our detailed results, representing all the different conditions of experiment, we will give, as a basis for our discussion of this topic, averages in which each analysis embodies the analytical results furnished by four different cheeses cured at the same given temperature. If a more detailed study is desired, the full tables in the Appendix can be examined. In general, we find in every individual cheese that temperature exerts a marked influence upon the changes taking place in the nitrogen compounds. The effect of temperature is modified by other conditions. In the following table, we consider, along with the temperature, the time factor. In this connection, we will mention a fact not included in the table,—in the cheese kept at 32° F. we found in the filtrate after removing paranuclein that, on neutralizing and heating, we obtained quite an abundant precipitate, amounting to 3 or 4 per ct. of the nitrogen in the cheese. This body disappeared entirely after 3 months and was not found at all in cheese kept at a higher temperature. We have not yet studied the nature of this substance, but it appears to be some kind of an intermediate product that disappears very quickly at ordinary temperatures and is to be found in appreciable quantities only in cheese kept at low temperatures.

TABLE II.—SHOWING EFFECT OF TEMPERATURE ON CHEESE-RIPENING.

Temperature of curing room.	Form of nitrogen compounds.	Nitrogen expressed as percentage of nitrogen in cheese.					
		1½ months.	3 months.	6 months.	9 months.	12 months.	18 months.
Degrees F.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
32	Total water-soluble.....	12.80	18.64	23.06	32.66	34 02	36.75
55	"	20.56	31.46	36.09	43.91	45 09	49.40
60	"	23 14	33.69	39.97	46.89	48.62	50.16
70	"	29.24	40.13	45 50	50.34	51.25	52.67

TABLE II.—SHOWING EFFECT OF TEMPERATURE ON CHEESE-RIPENING.—(*Con.*)

Temperature of curing room.	Form of nitrogen compounds.	Nitrogen expressed as percentage of nitrogen in cheese.					
		1½ months.	3 months.	6 months.	9 months.	12 months.	18 months.
Degrees F.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
32	Paracasein monolactate.	20.58	43.14	36.55	43.00	34.48	21.37
55	"	33.01	33.66	35.10	25.61	19.26	19.45
60	"	13.89	18.81	19.94	16.15	12.32	9.45
70	"	13.24	13.45	18.62	11.83	10.10	7.86
32	Paranuclein ..	1.27	4.05	3.44	4.47	4.15	4.12
55	" ..	2.39	5.34	4.25	4.27	3.64	3.68
60	" ..	2.54	4.71	3.90	4.23	3.59	4.73
70	" ..	2.03	3.71	2.68	3.13	2.45	2.60
32	Caseoses......	1.05	2.97	5.24	4.29	4.17	5.06
55	"	4.08	4.50	5.03	4.76	4.73	4.27
60	"	3.44	6.14	6.03	5.07	3.68	3.00
70	"	4.07	4.63	3.37	4.24	4.12	3.20
32	Peptones	1.30	2.23	4.53	4.36	4.53	4.17
55	"	3.90	4.95	3.99	3.10	3.72	2.84
60	"	3.33	5.99	4.70	3.44	4.03	1.80
70	"	6.81	5.45	3.67	3.33	3.51	1.50
32	Amides	4.82	6.36	8.70	17.55	18.73	19.44
55	"	8.69	14.33	19.55	27.05	29.00	31.66
60	"	12.16	14.55	21.39	28.84	31.14	33.54
70	"	13.86	22.20	30.80	32.68	34.65	37.19
32	Ammonia	0.61	0.61	1.21	1.91	2.14	3.98
55	"	1.50	2.42	3.30	4.69	5.57	6.95
60	"	1.67	2.54	3.89	5.43	6.12	7.35
70	"	2.47	4.22	5.71	6.91	7.49	8.19

A study of Table II enables us to make the following statements:

(1) At any given time, the amount of water-soluble nitrogen compounds formed in cheese is greater at the higher temperatures. Moreover, the increase of water-soluble nitrogen compounds is roughly proportional to the increase of temperature. Averaging all our results, we find approximately an increase of 0.5 per ct. in these compounds for each increase of one degree of temperature within the limits of temperature employed.

(2) In general, especially after the first few weeks, the paracasein monolactate decreases in cheese with increase of temperature. Averaging all our results, we have 33.19 per ct. of the nitrogen compounds existing in the form of paracasein monolactate at 32° F., 27.68 per ct. at 55° F., 15.09 per ct. at 60° F. and 12.52 per ct. at 70° F. This general tendency is in complete har-

mony with the belief that paracasein monolactate furnishes the material for the water-soluble nitrogen compounds.

(3) The amount of paranuclein found in cheese kept at different temperatures appears to be independent of the temperature until after 9 months, when there is a decrease of paranuclein with increase of temperature. In the early stages of cheese-ripening, paranuclein appears to be slow in formation at the lowest temperature and reaches its maximum only after some months.

(4) So far as our results show, the relation of temperature to the formation of caseoses is somewhat variable. The general tendency in the early months of ripening is in the direction of an increase of caseoses with increase of temperature, while the reverse is true in the later months.

(5) In the case of peptones, there is increase with higher temperatures during the first 3 months, after which the tendency is reversed.

(6) The amido compounds increase in amount with increase of temperature. From 32° F. to 60° F., the increase is almost directly proportional to temperature, there being an average increase of about 0.4 per ct. of amido compounds for each increase of one degree of temperature. From 60° F. to 70° F., the increase is more rapid, on an average, than below 60° F., being about 0.5 per ct. for each degree of temperature.

(7) In the case of ammonia, we find the same general relation to temperature that is found in the amido compounds. From 32° F. to 60° F., the ammonia increases, on an average, 0.1 per ct. for each degree of temperature, while from 60° F. to 70° F. the increase is at the rate of .13 per ct. for one degree.

(8) Summarizing our results, we find that, other conditions being uniform, (a) the water-soluble nitrogen compounds in cheese increase, on an average, very closely in proportion to increase of temperature; (b) from the average of our results, there is an increase of 0.5 per ct. of water-soluble nitrogen compounds for an increase of one degree of temperature between the limits of 32° F. and 70° F.; (c) the amido compounds and ammonia are formed in the cheese more abundantly at higher temperatures and accumulate in the cheese, while the other water-soluble compounds of nitrogen and also paracasein monolactate do not ap-

pear to be regularly influenced by temperature in the early stages of ripening, but after some months they decrease in quantity with increase of temperature.

THE RELATION OF MOISTURE IN CHEESE TO THE CHEESE-RIPENING PROCESS.

In order to study the effect of moisture in cheese upon the chemical changes taking place in the nitrogen compounds, two sets of cheeses were made for comparison, 4 different cheeses in each set being made under parallel conditions. The cheeses designated in the Appendix as 42-A, B, C, D were covered with melted paraffin, in order to retard the evaporation of water from the cheese. Those designated as 39-A, B, C, D were left in the usual condition. These cheeses were all kept in the same curing-room at a temperature of 55° F. The detailed analytical results in the case of each cheese can be found in the Appendix. In the tabulated results following, we give the averages obtained with the 4 different cheeses in each set of experiments, those that were covered with paraffin being indicated as 42, the others as 39.

TABLE III.—SHOWING EFFECT OF MOISTURE IN CHEESE ON CHEESE-RIPENING.

No. of cheese.	Form of nitrogen compounds.	Nitrogen expressed as percentage of nitrogen in cheese.					
		1½ months.	3 months.	6 months.	9 months.	12 months.	18 months.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
39	Total water-soluble......	17.32	27.09	31.76	39.09	39.80	42.77
42	" "	17.14	27.40	36.41	46.59	54.52	56.76
39	Paracasein monolactate..	24 89	41.59	35.43	28 81	21.70	13 72
42	" "	21.17	30.42	49.29	20.16	9 81	5 30
39	Paranuclein....	2.70	5 32	4 77	4 20	3.79	4 10
42	"	0.87	4 35	4 45	4.89	8.01	7 90
39	Caseoses	2.99	5.80	4.24	4.41	4.19	4 26
42	"	3.58	3.64	5 38	5 06	4.32	4 70
39	Peptones	2.12	4 09	3 75	3 57	3.97	1.95
42	"	4 49	4 80	6.19	4.00	4.43	3.20
39	Amides.........	7.50	9.79	16 00	21.65	22.89	26.73
42	"	7.22	12.59	17.12	26.03	29 44	29.00
39	Ammonia......	1 34	2 15	3 04	4 17	4 53	5 72
42	"	0.98	1.99	4.26	6 52	8 27	12 16
39	Water.........	36 40	35.27	32 41	27.86	28 02	27.75
42	"	35 96	35 00	33.37	33 24	32.66	32.10

Comparing the results presented in Table III, we notice the following points of difference:

(1) The cheeses covered with paraffin had somewhat less water when made but the others lost water more rapidly, so that at the end of 3 months their water content was about the same. After this the paraffined cheese contained considerably more water, the difference increasing with age, until at the end of 12 months it was over 4.5 pounds per 100 pounds of cheese.

(2) During the first 3 months, the amount of water-soluble nitrogen compounds was about the same in both kinds of cheese, but from this point the amount increased more rapidly in the cheeses covered with paraffin, that is, in those cheeses containing more moisture. The difference becomes more marked at each succeeding analysis.

(3) After 6 months the paracasein monolactate disappears much more rapidly in the cheeses containing more moisture, the difference increasing up to 12 months.

(4) In the cheeses containing more moisture, the paranuclein increases in amount during the whole period of study, while in the other cheeses there is comparatively little change during the last 9 months.

(5) In respect to caseoses, there is little difference in the results as to quantities, except that after 3 months, the more moist cheese contains rather more caseoses.

(6) Peptones became abundant more rapidly in the paraffined cheeses and continued so during the entire period of investigation.

(7) The amount of amides was greater in the moist cheeses after the first month and a half and continued so to the end.

(8) The amount of ammonia was greater in the moister cheese after 6 months and became increasingly so at each successive analysis.

(9) A general review of these results indicates the formation of larger amounts of water-soluble nitrogen compounds in cheese containing more moisture, other conditions being uniform.

THE RELATION OF SIZE OF CHEESE TO CHEESE-RIPENING.

In Bulletin No. 207 we report a study of the influence of the size of cheese upon the rapidity of evaporation of water from the

cheese. Our results showed that the loss of moisture is always greater in smaller-sized cheeses. This is what might naturally be expected, since the amount of external surface exposed for evaporation is greater, relative to weight, in small than in large cheeses. Hence, difference in size of cheese practically means difference in rapidity of loss of moisture, the larger cheese retaining its moisture content longer. We should expect, then, to find essentially the same differences of ripening in cheeses of different size that we find in cheeses having a different moisture content. To make a study of this point, we present below in Table IV some data showing at different stages of ripening the amounts of derived nitrogen compounds found in cheeses weighing respectively 30 and 10 pounds approximately. The data represent averages of 4 different lots of cheeses cured at 55° F. The detailed analyses can be found in the Appendix under cheeses No. 37-A, B, C, D and No. 39-A, B, C, D.

TABLE IV.—SHOWING EFFECT OF SIZE OF CHEESE ON CHEESE-RIPENING.

Weight of cheese.	Form of nitrogen compounds.	Nitrogen expressed as percentage of nitrogen in cheese.					
		1½ months.	3 months.	6 months.	9 months.	12 months.	18 months.
Lbs.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
10	Total water-soluble......	17.32	27.09	31.76	39 09	39.80	42.77
30	" "	20.56	31.46	36.09	43.91	45.09	49 40
10	Paracasein monolactate..	24.89	41.59	35.43	28.81	21.70	13.72
30	" "	33.01	33.66	35.10	25 61	19.26	19.45
10	Paranuclein ...	2.70	5.32	4.77	4.20	3.79	4 10
30	" ...	2 39	5.34	4.25	4.27	3.64	3.68
10	Caseoses	2 09	5.80	4.24	4.41	4.19	4.26
30	"	4 08	4.50	5 03	4.76	4 73	4 27
10	Peptones......	2.12	4.09	3.75	3.57	3.97	1.95
30	"	3.90	4.95	3.99	3.10	3.72	2.84
10	Amides	7.50	9.79	16.00	21.65	22 89	26.73
30	"	8 69	14.33	19.55	27.05	29 00	31.66
10	Ammonia	1.34	2.15	3.04	4 17	4.53	5.72
30	"	1.50	2.42	3.30	4.69	5.57	6.95
10	Water	36.40	35.27	32.41	27.86	28.02	27.75
30	"	36 31	35.11	33 46	32.29	31.54	28.56

An examination of Table IV shows in brief that the larger cheeses contained more moisture after the early stages of ripen-

ing and that there was a more rapid increase in the formation of total water-soluble nitrogen compounds, especially of amides and ammonia, than in the smaller cheeses.

THE RELATION OF SALT IN CHEESE TO CHEESE-RIPENING.

In Bulletin No. 203 of this Station, page 241, attention is called to the fact that salt exerts a retarding influence upon the proteolytic action of enzymes in cheese. Since the results given there were secured with cheese made and kept in the presence of chloroform, it was desired to make a study of the influence of salt upon the ripening process in cheese normally made and kept under normal conditions. For the purpose of such a study, 6 different lots of cheese were made under normal conditions as nearly alike as possible. In each lot there were 4 to 8 cheeses, weighing 10 or 30 pounds each and salt was added to these in proportions varying as follows: no salt, 1.5, 2.5, and 5 pounds of salt for 1000 pounds of milk. During the ripening 1 lot was kept at 32° F., 3 at 55° F., 1 at 60° F. and 1 at 70° F. The detailed analytical results are given separately for each lot of cheese in the Appendix. In Table V we give the averages of the 4 lots of larger cheeses kept at the different temperatures. Whether we consider each lot of cheeses by itself or their averages, the results are strikingly concordant in respect to the effect of salt upon the formation of nitrogen compounds in the ripening process.

It has been a fact long observed by cheesemakers that increase of salt in cheese delays the rapidity with which the cheese becomes marketable, but no detailed chemical study has previously been made of the subject in this country. Decker[1] made a brief study of the influence of varying amounts of salt upon normal cheddar cheese in respect to texture, flavor and moisture, but the study was continued only one month and no attention was given to the products of proteolysis.

We are to regard the salt in cheese as being in solution in the whey held by the cheese, practically forming a dilute brine. In common practice, cheesemakers add from 2 to 2½ pounds of salt to the curd made from 1000 pounds of milk. Cheese thus salted contains about 1 per ct. of salt. Such cheese usually contains

[1] Ann. Rept. Wis. Exp. Sta. **11**: 220 (1894).

about 35 to 37 per ct. of water. Consequently, under such conditions we should have approximately a 3 per ct. brine. It is evident that in proportion as a cheese loses moisture by evaporation, the salt brine remaining becomes more concentrated with the advancing age of the cheese.

TABLE V.—SHOWING EFFECT OF SALT ON CHEESE-RIPENING.

Amount of salt used for 1000 lbs. of milk.	Form of nitrogen compounds.	Nitrogen, expressed as percentage of nitrogen in cheese.					
		1½ months.	3 months.	6 months.	9 months.	12 months.	18 months.
Lbs.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
0	Total water soluble	23.42	34.26	40.52	49.10	51.38	53.96
1½	"	21.80	32.10	37.67	44.13	45.88	50.73
2½	"	21.67	29.92	34.73	42.93	43.52	44.65
5	"	18.84	27.70	31.70	37.64	38.19	39.62
0	Paracasein monolactate.	17.33	27.06	23.27	21.82	16.75	12.56
1½	"	20.86	28.43	26.16	22.38	17.98	12.61
2½	"	21.81	24.47	28.30	23.54	18.04	13.74
5	"	20.73	29.02	32.49	28.81	23.41	11.71
0	Paranuclein ..	1.85	4.44	3.80	4.66	3.83	3.44
1½	" ..	2.13	4.47	3.52	4.01	3.72	3.89
2½	" ..	2.27	4.55	3.51	3.80	3.30	3.34
5	" ..	1.98	4.35	3.42	3.63	3.23	2.96
0	Caseoses.....	3.41	4.94	4.94	5.60	4.95	3.87
1½	"	3.24	5.02	5.17	4.53	3.69	4.04
2½	"	3.21	4.14	4.98	4.16	3.97	3.84
5	"	2.75	4.14	4.58	4.08	4.05	3.77
0	Peptones	4.86	5.02	4.84	3.47	4.13	2.69
1½	"	3.50	5.16	4.29	3.54	4.87	3.40
2½	"	4.20	4.02	4.02	3.97	3.98	2.07
5	"	2.91	4.42	3.74	3.25	2.81	2.14
0	Amides	10.22	15.86	22.18	28.89	32.19	35.09
1½	"	10.46	14.77	20.13	27.31	29.33	32.36
2½	"	9.78	13.83	19.20	26.72	27.61	29.57
5	"	8.82	12.97	17.34	23.21	24.40	24.81
0	Ammonia	1.67	2.96	4.64	6.54	7.77	8.89
1½	"	1.67	2.53	3.69	4.69	5.36	7.04
2½	"	1.51	2.36	3.13	4.30	4.54	5.83
5	"	1.41	2.03	2.64	3.43	3.61	4.70
0	Per ct. water in cheese..	39.27	38.22	35.60	35.22	34.09	30.96
1½	" ..	36.66	35.60	33.50	32.62	31.61	28.80
2½	" ..	35.69	34.43	32.31	31.54	30.99	27.68
5	" .	33.63	32.62	29.52	29.88	28.61	26.97
0	Per ct. salt in cheese	0	0	0	0	0	0
1½	"	0.59	0.70	0.84	0.94	0.92	......
2½	"	0.82	1.20	1.15	1.26	1.27	......
5	"	1.29	1.50	1.62	1.87	1.83	......

A study of the data contained in Table V enables us to make the following statements:

(1) The amount of salt retained in cheese is not proportional to the amount of salt added to the curd. While salt was added to the different cheeses in the ratio of 1: 1.67: 3.33, the salt retained in the cheese was in the ratio of 1: 1.40: 2.20. Of necessity, a considerable proportion of the salt added to cheese curd passes into the whey. Moreover, we have found by examining different portions of the same cheese that the salt is not commonly distributed with perfect uniformity through the cheese mass.

(2) An increase of salt in cheese-curd results in decreasing the amount of moisture held in cheese. This fact is very strikingly shown by the figures in Table V. The cheese containing no salt retained most moisture, and increasing additions of salt decreased the amount of moisture held in the cheese. The same general relation held true throughout the whole period of investigation.

(3) An increase of salt in cheese was accompanied by a decrease in the amount of water-soluble nitrogen compounds and this was true through the whole 18 months of the investigation. While this influence of salt is more noticeable in the case of the amido compounds and ammonia, it is clearly evident in the case of the paranuclein, caseoses, and peptones.

(4) The paracasein monolactate disappears less rapidly in the cheeses containing more salt.

It is readily seen from the results embodied in Table V that the rapidity of formation of water-soluble nitrogen compounds is decreased in the presence of increased amounts of salt in cheese. The question arises whether this is due directly to a retarding action of salt upon the agencies that cause cheese-ripening or whether it is due to the effect of salt in decreasing the amount of moisture held in cheese. It is true that some of the observed differences in proteolysis can be accounted for by the difference in moisture content noticed in the various cheeses. While this set of experiments does not clearly demonstrate that salt has in itself a direct retarding effect upon the cheese-ripening process, we have some results obtained with another experiment which indicate that salt has a retarding effect upon proteolysis in cheese. In some

experiments made in another line of work, one (A) cheese was unsalted and another (B) salted at the rate of $2\frac{1}{2}$ pounds for 1000 pounds of milk. The amount of moisture in the two cheeses was nearly the same, the salted cheese containing a little more than the unsalted, owing to the conditions of manufacture. At the end of 12 months, the amount of water-soluble nitrogen was 40.47 per ct. of the nitrogen in the unsalted cheese, while, in the salted cheese, it was 32.83 per ct. In this case salt clearly exerted a retarding influence upon the formation of water-soluble nitrogen compounds. Then, again, some work carried on with milk, where there was no difference of water-content, indicates the same retarding action of salt. We shall give the subject further experimental study under conditions that more completely eliminate wide differences of moisture content in the cheese.

THE RELATION OF VARYING AMOUNTS OF RENNET TO CHEESE-RIPENING.

In Bulletin No. 54, page 267, are given the results of some experiments made in 1892 at this Station, when a comparison was made of the amount of water-soluble nitrogen formed in cheeses made with 3 and 9 ounces of rennet-extract per 1000 pounds of milk. Considerably larger amounts of soluble nitrogen were found when the larger amount of rennet was used. In 1899 some further experiments were made, using 3 and 6 ounces of Hansen's rennet-extract for 1000 pounds of milk. The cheeses were so made as to contain about the same amount of moisture. In each case, one cheese was covered with paraffin in order to delay the evaporation of moisture, and the other cheese was left in the usual condition. The results of analysis are given below.

TABLE VI.—SHOWING EFFECT OF DIFFERENT AMOUNTS OF RENNET UPON CHEESE-RIPENING.

Age of cheese.	Amount of rennet-extract used for 1,000 pounds of milk.	Condition of cheese.	Water in cheese.	Nitrogen expressed as percentage of nitrogen in cheese in form of— Water-soluble nitrogen.	Paranuclein, caseoses and peptones.	Amides.	Ammonia.
Months.	*Ounces.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	3	Normal......	37.54	18.90	10.31	8 36	......
"	6	"	38 06	23 40	13 37	9 47	......
"	3	Paraffined....	38 45	18 20	9.95	8 29	......
"	6	"	38 56	24 90	15 30	9.63	......
3	3	Normal......	35 59	26 70	13 34	12 00	1.87
"	6	"	36.25	29 70	15.40	12 50	1.86
"	3	Paraffined....	37.97	27.90	13 39	12 60	1.96
"	6	"	37 61	33 20	16.35	14.70	2 18
6	3	Normal	33 58	29 80	12.02	16 20	2.09
"	6	"	33 51	35 40	15 11	18 20	2 60
"	3	Paraffined....	37.59	31.80	12 84	17 30	2 23
"	6	"	36.79	36.80	16 76	17.30	2.70
9	3	Normal......	31.84	37.30	13 47	21.20	2.59
"	6	"	30.63	35 50	13 00	20.00	2.50
"	3	Paraffined....	36.81	38.90	14 93	20.30	3 73
"	6	"	35.40	45 20	14 36	26 60	4.26
12	3	Normal......	28.13	38 00	12 05	22.10	4 10
"	6	"	29.98	42.40	14 38	24 00	3 60
"	3	Paraffined....	36.07	40.40	14 10	23 60	2.93
"	6	"	34.51	48 10	15 34	27.50	4 60
15	3	Normal......	26.73	39.10	12 05	22 90	4.53
"	6	"	25.97	43 60	13.19	25 50	4 31
"	3	Paraffined....	34 35	41.20	12 96	23.80	4 92
"	6	"	33 21	49.90	16 87	28.00	5 54
24	3	Normal......	24.76	42 70	12 30	25.10	5.06
"	6	"	23 33	48 50	14.54	28.50	5 84
"	3	Paraffined....	30 93	46 40	11 34	28.70	6.52
"	6	"	28 22	50 20	11.75	30.80	7 92

The data embodied in Table VI show quite generally a greater increase of water-soluble nitrogen compounds in the cheese containing the larger amount of rennet, other conditions being the same. The cheeses covered with paraffin contain more moisture than those not so covered and, as we should expect, show a larger increase of soluble nitrogen compounds than do the other cheeses; but here also the cheese containing the larger amount of rennet ripens more rapidly than the one containing less rennet.

If we examine the different classes of the water-soluble nitrogen compounds, we notice that the increase caused by increased use of rennet is more noticeable in the case of the paranuclein,

caseoses and peptones than in the case of the amides and ammonia, especially during the first 6 or 9 months. After a year, the tendency is for a greater difference among the amides caused by increased use of rennet than between the other soluble nitrogen compounds.

These results are in harmony with some work done by Babcock, Russell and Vivian,[1] who used 3, 9, 12, 18 and 24 ounces of rennet-extract per 1000 pounds of milk and made analyses of the cheese at 1, 2 and 6 months. In this period of time, they found that, while there was a constant increase in the amount of total water-soluble nitrogen compounds when there was an increase in the amount of rennet used, this increase came mostly to the caseoses and peptones, the amides and ammonia remaining quite constant.

DISCUSSION OF RESULTS.

GENERAL STATEMENT OF RESULTS.

Reviewing briefly the results that have been presented in the preceding pages, we have found that different conditions affect the chemical changes in the nitrogen compounds of cheese as follows:

(1) *Time.*—The formation of water-soluble nitrogen compounds increases as cheese ages, other conditions being uniform. The rate of increase is, however, not uniform, since it is much more rapid in the early, than in the succeeding, stages of ripening.

(2) *Temperature.*—The amount of soluble nitrogen compounds increases, on an average, quite closely in proportion to increase of temperature, when other conditions are uniform.

(3) *Moisture.*—Other conditions being alike, there is formed a larger amount of water-soluble nitrogen compounds in cheese containing more moisture than in cheese containing less moisture.

(4) *Size.*—Cheeses of large size usually form water-soluble compounds more rapidly than smaller cheeses under the same conditions, because large cheeses lose their moisture less rapidly and after the early period of ripening have a higher water content.

[1] Ann. Rept. Wis. Expt. Sta., **17**: 102 (1900).

(5) *Salt.*—Cheese containing more salt forms water-soluble nitrogen compounds more slowly than cheese containing less salt. This appears to be due, in part, to the direct action of salt in retarding the activity of one or more of the ripening agents and, in part, to the tendency of the salt to reduce the moisture content of the cheese.

(6) *Rennet.*—The use of increased amounts of rennet-extract in cheese-making, other conditions being uniform, results in producing increased quantities of water-soluble nitrogen compounds in a given period of time, especially such compounds as paranuclein, caseoses and peptones.

(7) *Acid* appears to be essential to the formation of water-soluble nitrogen compounds in normal cheese-ripening, but the exact influence of varying quantities of acid upon the chemical changes of the ripening process has not yet been fully studied.

TRANSIENT AND CUMULATIVE PRODUCTS IN CHEESE-RIPENING.

In studying the influence of various conditions upon the chemical changes of the nitrogen compounds in the normal cheese-ripening process, we have noticed that the compounds grouped under the names, paracasein, caseoses and peptones, usually vary within comparatively narrow limits and do not appear to accumulate in the cheese in constantly increasing quantities. These compounds do not appear to show much definite regularity in the amounts formed under different conditions. On the other hand, amido compounds and ammonia accumulate in increasing amounts from the early age of the cheese during the whole process of normal ripening. The difference in the apparent behavior of these different classes of nitrogen compounds is most readily explained by regarding the compounds first formed in cheese-ripening as intermediate transient products. Thus we find paranuclein, caseoses and peptones present in the earliest stage of cheese-ripening, and they show a tendency to increase somewhat for a period of time and then decrease. Just what the chemical relation of these compounds is to paracasein or to paracasein monolactate, we are unable to say. It is probable that the molecule of the proteid compound first splits into paranuclein and caseoses or some closely related compounds and from one or both these

classes of compounds are formed peptones. Whatever may be the precise chemical relation and order of formation, the point we wish to keep in mind is that the amounts of these compounds do not increase regularly or accumulate continuously in the cheese. The extent to which any accumulation occurs in these transient stages depends upon the conditions of ripening. For example, at low temperatures, the transient nitrogen products formed appear to pass into other forms less rapidly than at higher temperatures and they tend to accumulate to some extent. This can be shown by comparing the results secured with cheeses ripened at 32° F. and at 70° F. These data are taken from Table II.

Age of cheese.	Percentage of nitrogen in form of paranuclein in cheese at		Percentage of nitrogen in form of caseoses in cheese at		Percentage of nitrogen in form of peptones in cheese at	
	32° F.	70° F.	32° F.	70° F.	32° F.	70° F.
Months.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1½	1.27	2.03	1.05	4.07	1.30	6.81
3	4.05	3.71	2.97	4.63	2.23	5.45
6	3.44	2.68	5.24	3.37	4.53	3.67
9	4.47	3.13	4.29	4.24	4.36	3.33
12	4.15	2.45	4.17	4.12	4.53	3.51
18	4.12	2.60	5.06	3.20	4.17	1.50

Now, quite different from the behavior of these compounds is that of amido compounds, which appear beyond question to result from the proteolysis of peptones, and of ammonia, which is formed from the decomposition of amides. Ammonia is an end-product and the amido-compounds are end-products to a considerable extent in cheese normally ripened. They therefore accumulate in increasing quantities under all conditions that favor their formation.

INFLUENCE OF PRODUCTS OF PROTEOLYSIS ON THE CHEESE-RIPENING PROCESS.

Attention has been called to the fact that chemical changes in the nitrogen compounds of cheese take place much more rapidly in the early stages of ripening than later. In our work we found that, in the first 3 months of the 18-month period of study, over 65

per ct. of the nitrogen was changed into the form of water-soluble compounds. How can we explain this observed fact that the rate of chemical change, as measured by the formation of water-soluble nitrogen compounds, decreases as the age of cheese increases? The most obvious explanation is associated with the generally observed fact that in fermentation changes the products of the process weaken the action of the ferment, often inhibiting it altogether. In cheese we have an accumulation of fermentation products in the form of water-soluble nitrogen compounds and apparently they serve to diminish the action of the agents that cause the changes.

In this connection, it is interesting to notice that the end-products, the amides and ammonia, appear to exert a stronger influence than do the other soluble nitrogen compounds in decreasing the action of the ripening agents. This is indicated by the following data taken from Table I.

AGE OF CHEESE.	Percentage of nitrogen in form of paranuclein, caseoses and peptones.	Percentage of nitrogen in the form of amides and ammonia.	Monthly average rate of increase of soluble nitrogen compounds for 100 lbs. of nitrogen in cheese.
1½ months.	9.05	11.44	15 0 lbs.
3 "	13 66	16.81	6.3 "
6 "	12.71	23.48	2 1 "
9 "	12.17	31.27	2.4 "
12 "	11.63	33.79	0.4 "
18 "	.....	37.00	0.4 "

Thus, it is seen that the first-formed products of cheese-ripening, paranuclein, caseoses and peptones, remain fairly uniform, while the amides and ammonia continuously increase.

WHY MOISTURE INFLUENCES THE CHEESE-RIPENING PROCESS.

We have seen that an increased moisture content in cheese favors more active chemical changes in the process of ripening. This may be due to one or both of two effects. First, moisture in itself may favor the activity of the ripening ferments. It is well known that moisture is necessary for the action of ferments and that increase of moisture above a certain amount increases their action. Second, the presence of increased amounts of

moisture serves to dilute the fermentation products and to that extent to counteract their unfavorable effect.

In ordinary cheese-ripening, there is a constant loss of moisture and this serves to make more concentrated the fermentation products which are increasing at the same time the moisture is decreasing. Accordingly, after 3 to 6 months, difference in moisture appears from the results of our work to exert a more marked influence upon the increased formation of soluble nitrogen compounds than in the early stages of ripening.

THE CHARACTER OF THE ACTION OF RENNET-EXTRACT.

In Bulletin No. 233 of this Station, the work of others has been confirmed in showing that the active constituent of rennet is a peptic ferment and that the part performed in cheese-ripening by rennet-extract is a peptic digestion, in which the chemical changes are largely confined to the conversion of paracasein monolactate into paranuclein, caseoses and peptones, only small amounts of amides being formed.

THE RELATION OF ACID IN CHEESE TO CHEESE-RIPENING.

In Bulletin No. 203, page 240, of this Station, we called attention to the fact that presence of acid in cheese favors the action of enzymes in the cheese-ripening process. In Bulletin No. 214, it was shown that acid performs a specific function in the cheese-making process, uniting with paracasein to form paracasein monolactate. It was also shown that paracasein monolactate appears to form the real starting point of the cheese-ripening process, since we have been unable to obtain soluble nitrogen compounds to any extent without the presence of paracasein monolactate and since this compound decreases in amount as soluble nitrogen compounds increase.

From our work previously done, it appears that acid in cheese is a prerequisite for its ripening. Additional work is required to show the specific influence of different amounts of acid upon the cheese-ripening process.

In examining the detailed data given in the Appendix in cheeses 41 A, B and D, which were kept at 32° F., it is noticeable that the amount of paracasein monolactate increases until the third month in the case of A and B and until the ninth month in

the case of D, being at those times much higher than usual in most other cases. This apparently tardy formation of paracasein monolactate is probably due to its imperfect extraction by salt solution, since in the early period of our work it was found difficult to extract it completely by ordinary treatment. By experiment it was found necessary to treat the residue with water at a temperature of 60° C. repeatedly in order to assure complete extraction. This behavior in cheese kept at low temperature suggests that some modified compound may be formed.

SOME PRACTICAL CONSIDERATIONS.

(1) *Quick-ripening and slow-ripening cheese.*—We have observed that certain conditions affect the rate of chemical changes taking place in the nitrogen compounds of cheese, that is to say, the rate of ripening. Certain conditions promote, while certain other conditions delay, these ripening changes. The general relation of different conditions to the rapid or slow rate of cheese-ripening may be shown by the following form of statement:

Conditions that may promote ripening:	Conditions that may retard ripening:
(1) Increase of temperature.	(1) Decrease of temperature.
(2) Larger amount of rennet.	(2) Smaller amount of rennet.
(3) More moisture in cheese.	(3) Less moisture in cheese.
(4) Less salt.	(4) More salt.
(5) Large size of cheese.	(5) Small size of cheese.
(6) Moderate amount of acid.	(6) No acid or excess of acid.

The element of time is a factor that modifies all other conditions, since, as a rule, increase of ripening results from an increase of the ripening-period, at least within the usual limits of the commercial life of cheese.

It will be observed that the factors of time and temperature and, to some extent, moisture are connected with the management of cheese after it is made, while the other conditions are associated with the process of manufacture. All of these conditions can be under control, so that the cheese-ripening process may be delayed or hastened. If a cheese is desired that ripens quickly, it should contain more than the usual amount of rennet, a moisture content of about 40 per ct. or more, and about 1 to $1\frac{1}{2}$ pounds of

salt for 1000 pounds of milk. Then it should be kept at a temperature between 60° F. and 70° F., if it is to be placed in the hands of consumers in one month or six weeks, and the atmosphere of the curing-room should have a humidity of 75 to 85 per ct. of saturation. However, it should be stated that cheese made to ripen quickly gives better commercial results when ripened at a lower temperature than 60° F. and held a longer time.

For a slow-ripening cheese, not more than $2\frac{1}{2}$ ounces of rennet-extract, such as Hansen's, should be used for 1000 pounds of milk, and about 2 to $2\frac{1}{2}$ pounds of salt. The other conditions that influence the moisture content of cheese, such as the temperature of heating the curd, the fineness of cutting curd, the amount of acid developed in the curd, cheddaring, etc., should be well under control, so as to produce a cheese containing, when fresh from the press, about 37 per ct. of water. For ripening, it should be kept at a temperature below 50° F. in a fairly moist atmosphere for a period of 3 to 6 months or more.

According to results given in Bulletins Nos. 184 and 234, cheese that ripens slowly is of higher commercial value than cheese ripened more quickly. The commercial life of cheese made to ripen quickly is much shorter than that of cheese made to ripen slowly; in other words, quick-ripening cheese must be consumed at an earlier age, since, after once reaching its best commercial condition, it deteriorates in quality more rapidly than slow-ripening cheese.

(2) *Relation of conditions of ripening to flavor in cheese.*—Increase of temperature favors a more rapid development of cheese-flavor, but the continuation of such a condition causes rapid deterioration of flavor. Sharpness of flavor is usually met with only in cheese cured above 60° F. High moisture content favors a more rapid development of cheese flavor and also more rapid development of objectionable flavors, especially when accompanied by higher temperature. Absence of salt in cheese is, in our experience, invariably accompanied by the presence of bitter flavor, the intensity increasing with increase of temperature. Increased amounts of salt, other conditions being uniform, tend to a slower formation of cheese flavor. Excess of acid in cheese delays the development of cheese flavor, while the sour taste

caused by the excessive acidity is seriously objectionable, especially in the early stages of ripening.

(3) *Relation of conditions of ripening to texture in cheese.*—High temperatures in cheese-ripening favor the production of a crumbly, dry, mealy texture and also the formation of holes. Excessive moisture with moderately higher temperature results in a texture of undesirable pasty softness. Excessive use of rennet-extract produces pasty texture. Large amounts of salt produce a texture that is dry, harsh and hard. Excess of acid acts much the same way. It is possible to overcome to some extent the faults of texture produced by excessive use of salt and acid by keeping the cheese for a long time in a moist atmosphere between 40° F. and 50° F.

APPENDIX.

CONDITIONS OF MANUFACTURE AND CURING.

The cheeses were made on different days between July 31 and Aug. 8, 1901. Four cheeses were made at a time. In each case, A contained no salt; B contained salt at the rate of 1½ pounds for 1000 pounds of milk; C, 2½ pounds; and D, 5 pounds. In the case of cheeses 37, 38, 40 and 41 (A, B, C, D), each cheese had an average weight of about 30 pounds, while the weight of each was about 10 pounds in cheeses 39 and 42 (A, B, C, D). Cheeses 41 (A, B, C, D) were kept at a temperature of about 32° F.; cheeses 37, 39 and 42 (A, B, C, D) were kept at 55° F.; 38, at 60° F.; and 40, at 70° F.

The methods of analysis used are those described in Bulletin No. 215 of this Station.

The method in use for extracting paracasein monolactate at the time this work began, was found to give incomplete results, especially in the case of cheese cured at low temperature. The difficulty was overcome by extracting with salt solution at a temperature of 60° C. and repeating the extraction a greater number of times.

Here and there discrepancies in the results of analysis may be found, such, for example, as a decrease of amides or ammonia at 12 months as compared with 9 months. Such discrepancies are to be attributed mainly to the difficulty of securing at different

times samples of cheese that are equally representative of the whole cheese mass, since the same cheese is apt to vary in composition in different parts.

TABLE VII.—GIVING DETAILS OF ANALYSIS OF INDIVIDUAL CHEESES.

KEPT AT 32° F.:—Cheese 41-A. Unsalted.

Age of cheese when analyzed.	Salt in cheese.	Water in cheese.	Nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—						
				Paracasein monolactate.	Total water soluble nitrogen compounds.	Paranuclein.	Caseoses.	Peptones.	Amides by tannic acid.	Ammonia.
Months	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1½	0	39.06	3.47	27.67	13.95	0.92	1.44	1.21	5.07	0.69
3	0	38.81	3.66	52.73	19.95	3.72	2.62	1.97	6.94	0.96
6	0	36.37	3.73	33.25	24.40	3.06	4.99	5.63	9.55	1.18
9	0	36.11	3.99	38.85	35.34	4.71	5.01	4.86	18.55	2.25
12	0	35.45	4.10	34.15	38.05	4.15	5.85	3.90	21.47	3.66
18	0	33.15	4.55	23.30	43.96	4.84	5.28	4.84	23.30	5.72
Cheese 41-B. 1½ lbs. salt for 1,000 lbs. milk.										
1½	0.70	36.89	3.58	19.28	13.58	1.40	1.01	1.29	6.15	0.56
3	0.74	36.39	3.68	51.09	19.84	4.34	4.24	3.59	6.52	0.54
6	0.87	35.45	3.86	33.54	25.39	3.32	6.22	4.30	10.36	1.30
9	0.98	33.34	4.17	44.85	33.33	4.60	4.17	4.32	18.23	1.92
12	0.90	32.91	4.18	34.21	36.12	4.31	3.35	6.46	20.34	1.67
18	....	30.71	4.70	20.22	40.00	4.25	5.53	4.89	21.28	4.04
Cheese 41-C. 2½ lbs. salt for 1,000 lbs. milk.										
1½	1.00	35.47	3.65	23.56	12.88	1.64	0.99	1.48	4.93	0.55
3	1.15	34.47	3.81	34.39	18.11	4.46	2.21	0.58	5.80	0.53
6	1.32	33.66	3.94	35.28	22.59	3.76	5.64	4.06	8.02	1.12
9	1.32	33.08	4.25	36.47	33.88	4.14	4.09	4.75	18.83	1.88
12	1.47	32.55	4.30	28.14	33.26	3.95	4.65	5.12	17.68	1.63
18	....	29.17	4.91	23.83	33.61	3.87	5.50	3.46	17.52	3.26
Cheese 41-D. 5 lbs. salt for 1,000 lbs. milk.										
1½	1.30	33.69	3.73	11.80	10.78	1.13	0.75	1.23	3.11	0.64
3	1.54	32.73	3.90	34.36	16.67	3.69	2.82	2.77	6.16	0.51
6	1.65	29.88	4.08	44.12	19.85	3.63	4.12	4.12	6.86	1.23
9	1.80	30.71	4.38	51.84	28.09	4.43	3.88	3.52	14.61	1.60
12	1.91	29.52	4.54	41.42	28.64	4.19	5.07	2.64	15.42	1.32
18	....	28.60	4.86	18.11	29.42	3.50	3.91	3.50	15.64	2.88
KEPT AT 55° F.:—Cheese 37-A. Unsalted.										
1½	0	39.28	3.40	22.35	22.10	2.18	4.29	5.00	8.82	1.76
3	0	38.19	3.51	28.78	33.34	5.18	4.79	4.56	16.35	2.45
6	0	37.11	3.63	32.78	40.22	4.57	5.95	4.30	20.90	4.40
9	0	35.50	3.93	24.94	50.39	5.60	6.11	2.59	29.52	6.62
12	0	34.82	4.13	16.22	51.33	4.12	5.81	6.05	32.93	7.27
18	0	31.10	4.68	11.75	55.56	2.99	4.49	2.56	36.54	8.98

TABLE VII.—GIVING DETAILS OF ANALYSIS OF INDIVIDUAL CHEESES—(*Continued*).

Cheese 37-B. 1½ lbs. salt for 1,000 lbs. milk.

Age of cheese when analyzed.	Salt in cheese.	Water in cheese.	Nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of—						
				Paracasein monolactate.	Total water soluble nitrogen compounds.	Paranuclein.	Caseoses.	Peptones.	Amides by tannic acid.	Ammonia.
Months	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1½	0.73	36 38	3.52	32.70	20 51	2.39	4 32	3.58	8.52	1.70
3	0.63	35.33	3 56	33.15	31 75	4.94	4.72	5.62	14 05	2.59
6	0 89	33 61	3 72	33 34	37.10	4 36	4 73	4 09	20.60	3 33
9	0.90	32.63	3 99	20.05	44 37	4.01	5.01	3 66	27.32	4 26
12	0.91	31.14	4 21	17.11	45 61	4.28	3.56	3.56	28.75	5 46
18	....	27.74	4.59	11 98	52 73	4.14	4 57	4.79	32.03	7.19

Cheese 37-C. 2½ lbs. salt for 1,000 lbs. milk.

1½	0 80	36.02	3.54	36.70	21.42	2.71	4 29	4 24	8 87	1 30
3	0 85	34 46	3 61	31.31	31.03	5.76	4 27	4 93	13.85	2.38
6	1.00	32.16	3 78	32.81	34.39	4 34	4 87	3.92	18.57	2.86
9	0.99	31.59	4.03	26.80	42 20	3.97	4.02	3 52	26.30	4 47
12	0 94	31.37	4.14	18 84	44.44	3 86	3.38	3 38	28.51	5.31
18	....	28.19	4.60	12.39	46 96	3 91	3 91	1 74	30.87	6 52

Cheese 37-D. 5 lbs. salt for 1,000 lbs. milk.

1½	1.01	33.56	3 67	40.30	18 20	2.29	3.32	2.78	8.56	1.25
3	1.09	32.46	3 77	41.38	29 71	5 46	4.24	4 67	13.05	2 28
6	1 60	30.95	3.86	41.45	32 65	3.73	4 56	3 63	18.14	2.59
9	1.64	29 44	4.11	30 66	38 69	3.50	3 89	2.63	25 06	3.41
12	1.71	28.81	4 26	24.88	38.98	3.29	3 76	1 88	25 83	4 23
18	....	27.20	4 89	11.66	42 33	3.68	4.09	2 25	27.20	5 11

KEPT AT 55° F. COVERED WITH PARAFFIN:—Cheese 42-A. Unsalted.

1½	0	39.55	3.46	21.39	18 61	0.81	4.80	4.34	7.51	1.16
3	0	38.15	3.65	41.37	29 59	3 78	4 82	4 55	13 70	2 74
6	0	36.30	3.92	38.26	43.37	5 92	7 09	9 85	19.65	5.61
9	0	37.50	4.13	10 17	57.89	6.29	5 81	7 02	30.03	8.72
12	0	35.26	4 51	4.43	73.40	17.52	5 77	5 54	33.26	11.09
18	0	34.58	4.66	2.15	68.45	10 52	5 37	2 57	33.48	16.53

Cheese 42-B. 1½ lbs. salt for 1,000 lbs. milk.

1½	0.55	36.17	3 60	15 56	17.95	0 89	3.33	4 83	7.78	1.11
3	4 50	34 69	3.77	20.69	29 71	4.84	4 03	4 78	13.69	2.23
6	0.66	33.56	4 06	49.02	37 69	4.68	5 17	5.12	17.74	4.92
9	0.50	32 75	4 32	20.61	45 84	4.86	5 09	2.45	26.39	6.94
12	0 47	32 85	4.68	5 56	56.63	6 41	3.85	5 79	31.20	9 40
18	....	32.99	4.98	3.21	62 25	12.45	4 42	3.01	28 90	13.46

TABLE VII.—GIVING DETAILS OF ANALYSIS OF INDIVIDUAL CHEESES—(*Continued*).

Cheese 42-C. 2½ lbs salt for 1,000 lbs. milk.

Age of cheese when analyzed.	Salt in cheese.	Water in cheese.	Nitrogen in cheese.	Nitrogen, expressed as percentage of hitrogen in cheese, in form of—						
				Paracasein monolactate.	Total water soluble nitrogen compounds.	Paranuclein.	Caseoses.	Peptones.	Amides by tannic acid.	Ammonia.
Months	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1½	0.88	35.02	3.60	23.34	17.67	0.94	3.39	5.00	7.22	1.11
3	0.91	34.67	3.77	31.57	27.33	4.88	3.18	5.33	11.94	1.86
6	0.75	32.94	4.02	52.74	34.08	3.98	5.03	5.18	15.92	3.98
9	0.71	31.96	4.47	22.38	44.52	4.70	4.47	3.89	24.83	6.49
12	0.65	31.10	4.73	12.69	46.52	4.23	4.23	3.38	27.49	7.19
18	....	30.72	4.96	9.27	51.82	4.64	5.04	3.83	28.43	9.88

Cheese 42-D. 5 lbs. salt for 1,000 lbs. milk.

1½	1.33	33.09	3.77	24.40	14.33	0.85	2.81	3.77	6.37	0.53
3	1.55	32.49	3.96	28.03	22.98	3.90	2.53	4.54	11.01	1.11
6	1.30	30.66	4.13	57.15	30.51	3.20	4.21	4.60	15.16	2.52
9	1.38	30.74	4.33	27.48	38.11	3.69	4.85	2.63	22.87	3.93
12	1.35	31.44	4.65	16.56	41.51	3.87	3.44	3.01	25.81	5.38
18	....	30.10	5.03	6.56	44.53	3.98	3.98	3.38	24.46	8.75

KEPT AT 55° F.:—Cheese 39-A. Unsalted.

1½	0	38.98	3.34	27.66	20.42	2.97	4.15	3.20	8.31	1.78
3	0	37.50	3.54	34.75	32.21	5.99	7.23	4.35	11.87	2.82
6	0	35.37	3.70	33.52	38.38	4.70	5.78	5.51	18.54	3.89
9	0	30.11	4.06	21.68	46.06	3.94	4.93	5.57	25.62	5.91
12	0	30.58	4.42	10.18	49.55	4.07	4.07	5.88	27.83	6.56
18	0	30.85	4.81	9.77	50.94	3.74	4.16	1.46	33.06	8.52

Cheese 39-B. 1½ lbs. salt for 1,000 lbs. milk.

1½	0.60	36.92	3.41	24.64	18.65	2.41	3.75	2.52	8.21	1.76
3	0.81	35.71	3.57	45.94	28.02	5.43	6.22	4.65	9.52	2.24
6	0.91	32.54	3.68	38.05	33.97	5.16	4.40	3.37	17.94	3.26
9	1.12	27.80	4.05	32.60	40.50	4.45	5.93	3.56	22.47	3.95
12	1.08	27.42	4.36	21.10	42.20	3.90	4.13	4.13	25.00	4.82
18	....	27.15	4.65	14.20	44.52	4.52	4.52	2.15	27.53	5.81

Cheese 39-C. 2½ lbs. salt for 1,000 lbs. milk.

1½	0.81	36.02	3.46	27.46	16.47	2.89	3.35	2.14	6.94	1.16
3	1.17	34.94	3.59	49.58	26.19	5.35	5.35	3.99	9.75	1.95
6	1.55	31.79	3.79	38.00	29.56	4.65	3.91	3.69	14.94	2.48
9	1.67	28.23	3.99	35.09	37.10	4.16	5.01	3.06	21.56	3.51
12	1.40	27.70	4.38	28.77	38.13	3.88	5.02	3.65	21.92	3.65
18	....	27.56	4.71	20.60	41.20	4.25	4.25	2.12	25.27	5.30

TABLE VII.—GIVING DETAILS OF ANALYSIS OF INDIVIDUAL CHEESES—(*Continued*).

Cheese 39-D. 5 lbs. salt for 1,000 lbs. milk.

Age of cheese when analyzed.	Salt in cheese.	Water in cheese.	Nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of— Paracasein monolactate.	Total water soluble nitrogen compounds.	Paranuclein.	Caseoses.	Peptones.	Amides by tannic acid.	Ammonia.
Months	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct*	*Per ct.*	*Per ct.*	*Per ct.*
1½	1.44	33 66	3.64	19.78	13.74	2.42	0.71	0 60	6 54	0.66
3	1.66	32.93	3.74	36.10	21.93	4.49	4 39	3 37	8.02	1 60
6	2.09	29 90	3.98	32.16	25.13	4 57	3 07	2 41	12.56	2 51
9	2.22	25 31	4 25	25.88	32.71	4.24	3 77	2 07	16 94	3 29
12	2.33	26.38	4.52	26.77	29.21	3.32	3.54	2.21	16 82	3.10
18	....	25.45	4.89	10.23	34.40	3.89	4 09	2.05	21.07	3.27

KEPT AT 60° F.:—Cheese 38-A. Unsalted.

1½	0	39.54	3.46	10.98	25 44	2.43	3 47	4.51	13.30	1.73
3	0	38.66	3.52	16.48	37.22	4.43	6 93	7.56	14.95	2 87
6	0	37.19	3.68	15.76	45.65	4.34	5.60	6.20	23.92	5.16
9	0	36.59	4.02	13.43	53.24	4.48	6.47	2.59	32.09	7.71
12	0	35.06	4.13	8 48	58.11	4.12	3 39	3.63	37.78	9.20
18	0	31.68	4 74	9.49	56.96	3.17	2.53	1 68	39.24	10 34

Cheese 38-B. 1½ lbs. salt for 1,000 lbs. milk.

1½	0.36	37.17	3.55	19 44	23.44	2 54	3.49	2 20	13 50	1.69
3	0.65	36.02	3.58	17.60	35.48	4 58	6 26	6.20	15.81	2.63
6	0.91	34.04	3 69	20.07	41.46	4.62	6.67	4 34	22.23	4.07
9	0.95	33.17	4.00	14.25	47.75	4 60	4.60	2.70	30.50	5 50
12	0.91	32.50	4.22	10.90	49.77	3.79	3.79	4 27	31 29	6.64
18	....	30.00	4 61	10.00	53.80	3 69	2 82	2 17	37.10	8.03

Cheese 38-C. 2½ lbs. salt for 1,000 lbs. milk.

1½	0.60	35.79	3 61	14.13	22.66	2.49	3.99	3.44	11.08	1.66
3	1.05	35.63	3 70	19.19	32.16	4.97	6.16	4.38	14.22	2 54
6	1.18	32.82	3 80	24.74	38.43	3.69	5.79	4.63	20 95	3 53
9	1.40	32.06	4.01	18.46	45.64	3.99	4.49	4.29	28.18	4.74
12	1.33	30.60	4.43	14.22	45.83	3.16	4.06	4 74	29.35	4 51
18	....	27.77	4.78	10.04	48.54	3.14	2.93	1 88	34.31	6.28

Cheese 38-D. 5 lbs. salt for 1,000 lbs. milk.

1½	1.33	33.78	3.72	11.02	21.02	2.69	2 80	3.17	10.75	1.61
3	1.73	33.34	3.78	21.96	29.90	4.87	5.19	5 82	13.23	2.12
6	1.53	30.26	3.96	19.19	34.34	3.43	6 06	3.64	18.44	2.78
9	2.10	30.25	4.23	18.44	40 91	3.83	4.73	4.16	24.59	3.78
12	1.79	28.80	4.59	15.69	40.75	3.27	3.49	3 49	26.15	4.14
18	....	26.38	4.84	8.26	41.33	2.89	3.72	1.45	26.65	4.75

TABLE VII.—GIVING DETAILS OF ANALYSIS OF INDIVIDUAL CHEESES—(*Concluded*).

KEPT AT 70° F.:—Cheese 40-A. Unsalted.

Age of cheese when analyzed.	Salt in cheese.	Water in cheese.	Nitrogen in cheese.	Nitrogen, expressed as percentage of nitrogen in cheese, in form of— Paracasein monolactate.	Total water soluble nitrogen compounds.	Paranuelein.	Caseoses.	Peptones.	Amides by tannic acid.	Ammonia.
Months	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct*
1½	0	39.19	3.61	8.31	32.20	1.88	4 43	8 70	14.68	2 49
3	0	37.23	3 61	10 25	46.54	4 43	5 43	5.98	25 21	5 54
6	0	31.73	3 90	11 28	51.80	3.28	3.23	3 23	34.36	7 80
9	0	32.66	4 18	10.05	57 42	3.83	4 79	3 83	35.40	9 57
12	0	31.05	4.43	8.13	58.02	2.93	4 74	2 93	36.57	10.84
15	0	27.89	4 75	5 69	59 37	2.74	3.16	1.68	41.27	10 53

Cheese 40-B. 1½ lbs. salt for 1,000 lbs. milk.

1½	0.45	36.18	3 66	12.02	29 67	2.19	4.15	6 94	13.66	2.73
3	0.77	34.64	3.70	11.89	41 08	4.00	4.86	5 24	22.71	4.32
6	0.68	30 91	3.96	17 68	46 73	2.27	3.08	4.42	31.31	6 06
9	0.94	31.34	4.25	10.35	51.07	2.82	4.33	3 48	33.18	7 06
12	0.95	29.87	4.44	9 69	52.03	2 48	4.05	5.18	36 94	7.66
15	....	26.75	4.61	8.24	56 40	3.47	3 25	1.74	39 04	8.89

Cheese 40-C. 2½ lbs. salt for 1,000 lbs. milk.

1½	0.86	35.47	3 58	12.85	29.72	2 23	3 58	7 15	14.25	2.51
3	1.15	33.17	3 78	12.97	38 37	3.02	3.92	6.19	21 43	3 97
6	1.08	30 60	4.00	20 36	43 50	2.25	3 60	3.45	29.25	5 00
0	1.35	29.41	4.26	12 44	50.00	3.10	4 04	3 33	32 57	6.10
12	1.32	28 45	4 47	10 96	50.56	2.24	3.80	2.69	34.90	6 71
15	....	25.57	4 95	8.69	49 50	2.43	3.03	1.21	35.56	7 27

Cheese 40-D. 5 lbs. salt for 1,000 lbs. milk.

1½	1.51	33.47	3.74	19 79	25.35	1.82	4.12	4 44	12 84	2 14
3	1.62	31.93	3 91	18.67	34 53	3.38	4.30	4 40	19 44	3 07
6	1.68	26 99	3 13	25 18	39 95	2.90	3 58	3 58	25.90	3.97
9	1.94	29.12	4.48	14.29	42.86	2.77	3 80	2.68	28.57	4.91
12	1.92	27 30	4.64	11.64	44 40	2.16	3 88	3 23	30.18	4.74
15	....	25.70	5 11	8 81	45.41	1.76	3.34	1.37	32.88	6.07

THE STATUS OF PHOSPHORUS IN CERTAIN FOOD MATERIALS AND ANIMAL BY-PRODUCTS, WITH SPECIAL REFERENCE TO THE PRESENCE OF INORGANIC FORMS.*

E. B. HART AND W. H. ANDREWS.

SUMMARY.

(1) Our commercial feeding stuffs of vegetable origin do not contain appreciable quantities of phosphorus in inorganic combination.

(2) The animal feeding materials, such as liver meal and dried blood, when representative, are also approximately free from this form of phosphorus. Commercial meat meal, liable to carry varying quantities of bone, does contain inorganic phosphorus dependent, of course, on the amount of bone present. The feces of a cow which were examined were also free from inorganic phosphorus.

(3) Germinated grains are rich in forms of soluble organic phosphorus.

(4) Germination, extending over a period of two weeks, of oats, corn and wheat, did not transform organic phosphorus into inorganic forms.

*A reprint of Bulletin No. 238.

INTRODUCTION.

The following research forms part of, and is preliminary to, an extended investigation to be carried on at this Station under the direction of Dr. W. H. Jordan, on the metabolism of phosphorus and sulphur in the animal body.

It is quite generally believed that phosphorus exists in plant substances, partly in organic combinations as nucleo-proteids, nucleins and lecithins and partly in inorganic forms, such as calcium, magnesium [1] and potassium phosphates. It is not difficult to understand how this view of the occurrence of phosphorus in vegetable tissue originated, since inorganic combinations form the basis of supply to the growing plant and since it is in the ash that we have chiefly studied the kinds and proportions of the inorganic plant constituents. Starting with the assumption that a considerable proportion of the phosphorus in animal and human vegetable foods is inorganic in form, our efforts have been directed towards the elaboration of a method for separating and quantitatively estimating, at least approximately, this form of phosphorus in vegetable and animal feeding stuffs.

It was also thought that, should the ratio of organic to inorganic phosphorus vary greatly in the different vegetable products, this fact might be made the basis of investigations as to the relative nutritive value of these products for specific purposes.

Such investigations could be undertaken, however, only after the evolution of a fairly safe method for the separation of inorganic from organic phosphorus.

DETAILS OF INVESTIGATION.

TOTAL PHOSPHORUS.

Before taking up the experimental details of the estimations of inorganic phosphorus, determinations of total phosphorus were made on a number of vegetable and animal products by both the magnesium nitrate and the Neumann methods. The Neumann method was tried particularly because it is convenient for use on large volumes of liquids—a condition which must be met in the separations involved in this inquiry.

Magnesium nitrate method.—This method is essentially the same as that used by the Association of Official Agricultural Chem-

(1) Sherman. U. S. Dept. Agr., Office Expt. Stas., Bul. 121.

ists:[1] 5 grams of material was well mixed in a platinum dish with 2-4 cc. of a solution of magnesium nitrate and incinerated at a low heat. In most cases a perfectly white ash was obtained. This residue was dissolved in dilute hydrochloric acid, and made up to 200 cc., an aliquot being taken for the estimation of total phosphorus.

Neumann method.—This is the method described by Neumann[2] and already used by Sherman:[3] 5 grams of material was placed in a Kjeldahl flask, 10-15 cc. concentrated sulphuric acid was added and the mixture was heated over a low flame until well charred. When partly cooled 5-10 grams of ammonium nitrate was added and the digestion continued. Further additions of ammonium nitrate were made from time to time to entirely oxidize and decolorize the mixture. On cooling, the residue was rinsed into a 200 cc. flask, diluted to the mark and an aliquot was taken for the determination of total phosphorus by the molybdate-magnesia method. The large amount of ammonium sulphate formed on neutralizing with ammonia seems to impede the precipitation of ammonium phospho-molybdate and only when a generous excess of ammonium molybdate was added—150 cc.—did we get a rapid separation of the "yellow" precipitate.

TABLE I.—COMPARISON OF METHODS FOR THE DETERMINATION OF PHOSPHORUS.

Substance.	Percentage of phosphorus found in air-dry material.	
	Magnesium nitrate method.	Neumann method.
	Per ct.	*Per ct.*
Corn	.313	.310
Oats	.355	.339
Wheat bran	1.548	1.537
Malt sprouts	.677	.670
Brewers' grains	.421	.419
Distillers' grains	.307	.303
Linseed meal	.789	.787
Oat straw	.135	.129
Alfalfa	.266	.267
Meat meal	4.073	3.971
Liver meal	1.034	1.029
Dried blood	.123	.126
Cow feces	.344	.353

(1) U. S. Dept. Agr., Bur. Chem., Bul. 46, rev. ed.
(2) *DuBois-Reymond's Archiv.* (Physiol. Abth.), 1897, pp. 552-553.
(3) *Jour. Amer. Chem. Soc.*, **24**: 1100 (1902).

The two methods yield practically the same results.

SEPARATION OF ORGANIC AND INORGANIC PHOSPHORUS.

Iwanow [1] has lately studied the changes occurring in the organic phosphorus combinations during the germination of vetch (*Vicia sativa*) and has reached the conclusion that there is a gradual decrease of organic phosphorus with corresponding increase of the inorganic forms as germination proceeds. The seeds were germinated in the dark. The method of separation used by Iwanow was as follows: 5-7 grams of the material was warmed on the water bath 10-15 minutes with 100-150 cc. of 1 per ct. acetic acid. After cooling, the precipitated proteid matter was separated by filtration through a small flannel filter and washed with water until about 500 cc. filtrate had been collected. For the determination of the inorganic phosphorus an aliquot from the 500 cc. was taken and precipitated directly with molybdate solution.

Zaleski, [2] working independently and on the same problem, evolved an almost identical method. This investigator recommends the use of either a 1 per ct. acetic acid or 0.2 per ct. hydrochloric acid solution, as the extracting reagent. As will be shown later in both of these methods, the cleavage action on soluble nucleins of the nitric acid contained in the molybdate solution is not sufficiently taken into account. It is true that Zaleski recommends that no extra nitric acid be added, he himself using only the ordinary molybdate solution.

Kossel [3] working on muscle extracts has used a mixture of tannin and 5 per ct. hydrochloric acid as the precipitant of proteids containing phosphorus.

Araki [4] has recently used this method, somewhat modified, in his studies of the decomposition of nucleic acids by enzymes. The method of Araki was as follows: 2 grams of a salt of nucleic acid was dissolved in 40 cc. of water and to this the enzyme was added. This solution was then diluted with an equal volume of water, 4 grams of sodium acetate added and tannin so long as a precipitate continued to be formed. The filtrate from this precipi-

(1) *Ber. deut. bot. Gesell.*, **20**: 366 (1902).
(2) *Ber. deut. bot. Gesell.*, **20**: 426 (1902).
(3) *Zeit. f. physiol. Chem.*, **7**: 9 (1883).
(4) *Zeit. f. physiol. Chem.*, **38**: 84 (1903).

tate, according to Araki, should contain any free phosphoric acid split off by the action of the enzyme. In our hands, as we shall show later, tannic acid in dilute mineral acid solution and tannic acid with sodium acetate both fail to precipitate completely the soluble nucleins contained in certain of our feeding materials. We do not assume to deny the accuracy of the results of these authors, recognizing the important fact that the constitution and consequent reaction of the nucleic acids with which these investigators worked may be entirely different from those that occurred in our materials.

Our preliminary work was done on whole oats, ground and air-dried. Five-gram samples were treated with 125 cc. of the extracting reagent for varying lengths of time with occasional vigorous shakings. The mixtures were then allowed to settle and the supernatant liquid was decanted through dry filters into 500 cc. flasks. The residue was washed by decantation with several portions of water until 500 cc. of filtrate had been collected. To 200 cc. of this filtrate 10 grams of ammonium nitrate was first added, and after heating the solution to 65° C. 50 cc. of ordinary ammonium molybdate solution was added, the whole kept at 65° C. for 15 minutes, then removed from the bath and allowed to stand for 1 hour. The precipitate was then filtered off, washed with a small quantity of water and the phosphorus estimated as magnesium pyrophosphate. This was supposed to be the inorganic phosphorus. The total soluble phosphorus was determined in another aliquot of 200 cc. by the Neumann method. The phosphorus in the insoluble residue, representing a mixture of nucleo-proteids, nucleins and lecithins, was also determined and designated as insoluble organic phosphorus. Tannin, with acetic and hydrochloric acids, under the conditions shown in the table below, was also tried. The molybdate solution used was one prepared according to the method adopted by the Official Agricultural Chemists.[1]

(1) U. S. Dept. Agr., Bur. Chem. Bul. 46, rev. ed.

TABLE II.—COMPARISON OF METHODS FOR SEPARATION OF FORMS OF PHOSPHORUS.

Sub-stance.	Treatment.	Total phos-phorus.	Percentage of phosphorus in air-dry material.		
			Insoluble organic phos-phorus.	Soluble phos-phorus.	Inorganic phos-phorus.
		Per ct.	Per ct.	Per ct.	Per ct.
Oats..	1% acetic 12 min. 55° C.	.355	.210	.142	.035
	" " room tem. 24 hours	......	.240	.116	042
	" " " " 40 "	......	.227	.138	.032
	" " " " 3 "	......	.252	.103	.017
	.2% hydrochloric, room tem. 40 hrs	......	.258	.092	.006
	.5% hydrochloric, 10 min. 55° C.	......	.184	.171	.014
	1% acetic, room tem. 17 hrs. tannin	......	.094	.244	Tannin interferes.
	.2% hydrochloric, room tem. 17 hrs tannin.	......	.206	.126	
	1% acetic 10 min. 55° C. tannin	......	.075	.240	
	.2% hydrochloric, 10 min. 55° C. tannin	......	.223	.109	

These results show how decided a variation may occur in the quantities of the different forms of phosphorus as estimated under varying conditions of manipulation. They also show in certain instances an apparent inorganic content appreciably large, while in others practically none was found, indicating again the influence of certain varying factors in the method of separation. That tannin fails to remove a large proportion of soluble organic forms is also very evident.

We next made the same separations with a number of materials, using, as the extracting reagents, 0.2 per ct. hydrochloric and 1 per ct. acetic acid solutions for forty hours at room temperature. The inorganic phosphorus was estimated by the same method as that used in the case of oats.

TABLE III.—COMPARISON OF ACETIC AND HYDROCHLORIC ACIDS FOR SEPARATION OF FORMS OF PHOSPHORUS.

Substance.	Acid used.	Total phosphorus.	Percentage of phosphorus in air-dry material.		
			Insoluble organic phosphorus.	Soluble phosphorus.	Inorganic phosphorus.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
Wheat bran	Acetic	1.548	.111	1.422	1.230
	Hydrochloric	....	.428	1.121	.120
Malt sprouts	Acetic	.677	.176	479	.389
	Hydrochloric	....	.213	.477	.350
Brewers' grains	Acetic	.421	.382	.042	.005
	Hydrochloric	....	.395	.032	.006
Distillers' grains	Acetic	.307	.229	.082	.022
	Hydrochloric	....	.244	.075	.022
Corn	Acetic	.313	.155	.163	.017
	Hydrochloric	....	.159	.153	.015
Alfalfa	Acetic	.266	.057	.205	.174
	Hydrochloric	....	.084	.189	.136
Linseed meal	Acetic	.789	.470	.327	.166
	Hydrochloric	....	.564	.195	.102
Liver meat meal	Acetic	1.034	.488	.618	.347
	Hydrochloric	....	.486	.585	.380
Dried blood	Acetic	.133	.099	.020	.019
	Hydrochloric	....	.080	.042	.045
Cow feces	Acetic	.344	.193	.159	.091
	Hydrochloric	....	.199	.141	.084

It will be noticed from these results that whenever there is a large amount of total soluble phosphorus there is also a corresponding increase in the amount of inorganic phosphorus. In but one instance—that of the hydrochloric acid extract of bran—did this fail to hold true. In all cases the character of the inorganic precipitate was greatly different from that of an ammonium phospho-molybdate precipitate. It was invariably of a flocculent, proteid-like nature and only on standing did the characteristic yellow precipitate begin to separate. This certainly indicated a slow cleavage of the organic phosphorus in the solution which was brought about by the excess of nitric acid in the molybdate reagent. In the case of the acetic acid extract from bran this cleavage was especially marked. Such conditions of manipulation certainly lead to results altogether too high for inorganic phosphorus.

To determine more definitely the point as to whether certain nucleic acids are so easily split up as our results indicated, we made preparations of these bodies from wheat bran and fresh corn germ meal. That from wheat bran was separated by Osborne's method (1) and gave a product extremely low in phosphorus,—less than 1 per ct.—and high in proteid matter. The filtrate from the pepsin digestion—a part of the Osborne method—showed an abundance of an easily cleavable organic phosphorus combination. This is in harmony with our other results, that the nucleins or salts of nucleic acid of wheat bran are extremely soluble in dilute acid solutions.

By Levene's method (2) we separated from wheat bran a nucleic acid carrying 7.59 per ct. of phosphorus and from fresh germ meal one containing 6.83 per ct. Both these products were soluble in water, yielding pale yellow solutions. When dissolved in water and tested as in the above method for the estimation of inorganic phosphorus, that is, with 50 cc. molybdic solution at 65° C. in the presence of ammonium nitrate, a flocculent precipitate first separates. This soon takes on a yellow color and the ammonium phospho-molybdate settles out.

It became apparent that a method estimating, at least approximately, the amount of inorganic phosphorus in our feeding materials and animal by-products, must take into account the amount of free acid in the precipitating reagent. With this point in view we first established the amount of nitric acid necessary to separate quantitatively ammonium phospho-molybdate when neutral ammonium molybdate was added to a neutral solution of inorganic phosphorus. We found that 2 cc. of nitric acid (sp. gr. 1.20) in 225 cc. of solution would cause quantitative separation in water extracts and in extracts made with 0.2 per ct. hydrochloric and neutralized with ammonia. In the 1 per ct. acetic acid extracts, neutralized with ammonia 4 cc. of 1.20 nitric acid is necessary because of the retarding action of the ammonium acetate on the separate of ammonium phospho-molybdate. 10 grams of ammonium nitrate was added to the above volume. Neutral am-

(1) Annual Report Conn. Agr. Exp. Station, 1901.

(2) *Jour. Amer. Chem. Soc.* **22**: 239 (1900).

monium molybdate was prepared by addition of ammonia to the ordinary molybdic solution, using litmus as an indicator.

Preliminary estimations showed that forty hours' extraction was entirely unnecessary. Three hours, the time required to thoroughly wash the residue, gave nearly as high total soluble phosphorus as forty hours. In the next table are presented results secured by the following methods: 5 grams of the sample was vigorously shaken with 125 cc. of the extracting reagent for 15 minutes; the mixture was then allowed to settle, was decanted through a filter paper into a 500 cc. flask and the residue washed with water until about 500 cc. of filtrate had been collected. 200 cc. of the filtrate was next neutralized with ammonia, using litmus as indicator, and 10 grams of ammonium nitrate added. The solution was then warmed to 65° C. and, in the case of the water and hydrochloric acid extracts, 2 cc. of 1.20 nitric acid and 25 cc. neutral ammonium molybdate were added. To the acetic extracts 4 cc. 1.20 nitric acid were added. The extracts were allowed to stand fifteen minutes at 65°, were then removed from the bath and after one hour were filtered. The phosphorus was estimated as the magnesium salt.

TABLE IV.—SEPARATION OF FORMS OF PHOSPHORUS USING MINIMUM AMOUNTS OF NITRIC ACID.

Substance.		Total phosphorus.	Percentage of phosphorus in air-dry material.	
			Total soluble phosphorus.	Inorganic phosphorus.
		Per ct.	*Per ct.*	*Per ct.*
Oats	Water	.355	.180	.00
	Acetic		.114	.00
	Hydrochloric		.096	.00
Bran (wheat)	Water	1.548	.356	.143
	Acetic		1.100	.055
	Hydrochloric		.951	.036
Malt sprouts	Water	.677	.548	.391
	Acetic		.489	.279
	Hydrochloric		.477	.017
Brewers' grains	Water	.421	.142	.007
	Acetic		.039	.007
	Hydrochloric		.040	.009

TABLE IV.—SEPARATION OF FORMS OF PHOSPHORUS USING MINIMUM AMOUNTS OF NITRIC ACID—(*Continued*).

Substance.		Total phosphorus.	Percentage of phosphorus in air-dry material. Total soluble phosphorus.	Inorganic phosphorus.
		Per ct.	*Per ct.*	*Per ct.*
Distillers' grains	Water	.307	.079	.012
	Acetic	....	.104	.005
	Hydrochloric	....	.069	.007
Corn	Water	.313	.276	.014
	Acetic	....	.203	.00
	Hydrochloric	....	.177	.00
Alfalfa	Water	.266	.196	.064
	Acetic	....	.182	.079
	Hydrochloric	....	.180	.079
Linseed meal	Acetic	.789	.327	.085
	Hydrochloric	....	.195	.088
Oat straw	Acetic	.135	.095	.028
	Hydrochloric	....	.086	.009
Wheat	Water	.390	.125	.028
	Acetic	....	.174	.040
	Hydrochloric	....	.172	.008
Blood	Water	.123	.029	.005
	Acetic	....	.028	.010
	Hydrochloric	....	.054	.00
Meat meal	Hydrochloric	4.073	1.387	.098
Liver meat meal	Hydrochloric	1.034	.486	.005
Cow feces	Hydrochloric	.344	.148	.004

These results clearly show that where the amount of nitric acid used in the determination of inorganic phosphorus was reduced to the minimum, there was a marked decrease in the amount of this form of phosphorus apparently present. This decrease is especially noticeable in the hydrochloric acid extracts. In fact the estimations by the use of hydrochloric acid, with the exceptions of alfalfa and linseed meal, we regard as indicating the absence of inorganic phosphates. The water and acetic acid extracts on bran and malt sprouts show considerably higher figures for inorganic phosphorus than the hydrochloric acid extracts. It will be observed that both these materials are rich in easily soluble organic combinations. That these combinations are more easily split up into inorganic forms by water alone and a 1 per ct. acetic acid than by 0.2 per ct. hydrochloric acid seems a possible explanation of the results secured. Even when bran has been extracted with a 1 per ct. solution of hydrochloric

acid for forty hours the inorganic estimation showed but 0.088 per ct., while the total soluble phosphorus was 1.26 per ct. We found it impossible to filter extracts of linseed meal and consequently could only prepare such extracts by decantation. This of course gave us a distinctly turbid solution. On precipitating with molybdate solution an unusually large flocculent precipitate resulted, difficult to filter and wash. It redissolved readily in ammonia. Also in the case of alfalfa a very large flocculent precipitate was formed on adding the molybdate solution. Later, working with sprouted grains, we estimated in one case as inorganic phosphorus 0.0118 gram magnesium pyrophosphate. This precipitate after ignition was unusually white. On dissolving it in dilute nitric acid and reestimating the phosphorus we weighed but .0017 gram of magnesium pyrophosphate. This is an extreme case, but it indicated that where we have a large flocculent proteid precipitate with our molybdic acid, soluble again in ammonia, there can be formed on the addition of magnesia mixture insoluble proteid-magnesia combinations convertible to magnesium oxide on ignition and weighed as magnesium pyrophosphate. With this precaution in mind we redetermined the inorganic phosphorus in alfalfa and linseed meal. On the first weighing as magnesium pyrophosphate they showed respectively .0072 gram and .0107 gram. On dissolving in dilute nitric acid we weighed as magnesium pyrophosphate .0006 gram and .0005 gram respectively. These figures are equivalent to .008 per ct. inorganic phosphorus in alfalfa and .007 per ct. in linseed meal, figures we still believe due to errors of manipulation.

EXPERIMENTS WITH THE USE OF TANNIN AND SODIUM ACETATE.

Since Araki has used this method as a means of separating nucleic acids from solutions containing organic and inorganic phosphorus, it was thought that it might be applied to our work. Extracts were made with 0.2 per ct. hydrochloric and 1 per ct. acetic in the usual way. To 200 cc. of the extract neutralized with ammonia, 12 grams of sodium acetate was added and then a solution of tannin until no further precipitate was formed. The mixture was then diluted to 250 cc., filtered through a dry filter and in 200 cc. the total phosphorus (supposedly inorganic) deter-

mined by the Neumann method. The reagents used were phosphorus free.

Below we give the results in percentages of air-dried material.

TABLE V.—SEPARATION OF FORMS OF PHOSPHORUS WITH TANNIN AND SODIUM ACETATE.

Substance.		Percentage of phosphorus in air-dry material.	
		Total phosphorus.	Inorganic phosphorus.
		Per ct.	*Per ct.*
Wheat	Water	.390	.087
	Acetic	....	.147
	Hydrochloric	....	.147
Bran	Water	1.548	.398
	Acetic	....	1.026
	Hydrochloric	....	.783
Distillers' grains	Water	.307	.080
	Acetic	....	.092
	Hydrochloric	....	.063
Malt sprouts	Water	.677	.528
	Acetic	....	.471
	Hydrochloric	....	.483
Brewers' grains	Water	.421	.115
	Acetic	....	.061
	Hydrochloric	....	.026
Oat straw	Water	.135	.094
	Acetic	....	.061
	Hydrochloric	....	.083

These results give further evidence that tannin and sodium acetate could not be used for the separation of organic and inorganic phosphorus in such materials.

METHOD ADOPTED.

The method we have finally adopted as giving results nearest the truth is that detailed above for the hydrochloric-acid extract of Table IV, with the following modification. After ignition the magnesium pyrophosphate is dissolved in dilute nitric acid and the phosphorus reestimated. This, as detailed above, is to prevent the error of weighing magnesium pyrophosphate contaminated with magnesium oxide. We do not expect the method in all cases to give absolute results. What we claim for it is that it reduces the hydrolyzing action of the reagents to a minimum,

but at the same time allows complete precipitation of inorganic phosphates.

In one experiment, when to a solution containing .0413 gram of inorganic phosphorus estimated as magnesium pyrophosphate, was added .500 gram of nucleic acid prepared from wheat bran, and the solution then subjected to the above method, the recovery was .0439 gram—a gain of .0026 gram by cleavage of the nucleic acid present. This .0026 gram of magnesium pyrophosphate calculated in percentage of phosphorus on a 2 gram sample is equal to .036 per ct. It can be readily seen, then, that estimations of inorganic phosphorus giving results as high as .036 per ct. in solutions rich in soluble organic phosphorus can easily be accounted for as coming by cleavage of organic phosphorus combinations.

Attempts have been made to remove the interfering proteids by precipitation with neutral ammonium molybdate in solutions cooled to 18° C. and in the presence of but 1 cc. 1.20 nitric acid in 250 cc. volume. This did bring about partial removal, but on warming the solutions with the addition of the extra 1 cc. of 1.20 nitric acid, necessary to precipitate the inorganic phosphorus, there was generally a further precipitation of proteid matter and consequent interference.

EXPERIMENTS WITH GERMINATED GRAINS.

Since Iwanow[1] and Zaleski,[2] working independently, have shown that during the germination in the dark of vetch and lupine a marked decrease in organic phosphorus with corresponding increase in inorganic forms appeared to take place, it became of interest to carry on similar work, using our own method for the separation of inorganic phosphorus. Both these workers used the ordinary molybdate solution containing free nitric acid in their inorganic determinations. For our work we selected corn, oats and wheat. These were germinated in pure quartz sand in the dark for periods of one and two weeks. At the end of these periods the grains were dried at 60° C., separated from the adhering sand and finely ground. After exposure to the air for a few

(1) *Ber. deut. Bot. Gesell.*, **20**: 366, 1902.

(2) *Ber. deut. Bot. Gesell.*, **20**: 426, 1902.

days the samples were bottled and analysis made by the hydrochloric acid method. Below we give the data and, for comparison, results obtained on the unground seeds. We also present data secured on the two weeks old germinated seeds by the Iwanow method. 50 cc. of ordinary molybdate were used to 200 cc. of extract. Iwanow does not state the exact quantity of molybdic solution which he used, so we are unable to repeat his method exactly.

TABLE VI.—PHOSPHORUS IN GERMINATED AND UNGERMINATED GRAINS.

Substance.	Time of germination.	Total phosphorus.	Total soluble phosphorus.	Percentage of phosphorus in air-dry material.	
				Inorganic phosphorus.	Iwanow method. Inorganic phosphorus.
		Per ct.	Per ct.	Per ct.	Per ct.
Wheat	Ungerminated..	.390	.172	.008	
	1 week	....	.211	.018	
	2 weeks......	....	.279	.031	.273
Corn	Ungerminated .	.313	.177	.00	
	1 week	....	.237	.011	
	2 weeks......	....	.312	.036	.212
Oats	Ungerminated..	.355	.096	.00	
	1 week......	....	.181	.032	
	2 weeks......	....	.302	.032	.217

We see from the above figures that during the germination of these seeds in the dark, there is a marked increase in soluble organic phosphorus combinations, but that according to our method of estimation the cleavage does not extend to the formation of inorganic phosphates. The increase of inorganic phosphorus accompanying the increase of total soluble organic phosphorus, is explained by the slight cleavage action of our reagents.

The Iwanow[1] method in our hands gives results in perfect agreement with his previously reported results—that is, that during germination in the dark there is a marked formation of inorganic phosphorus.

The discrepancy in the two results appears to be due to differences of method. Araki[2] working on the action of certain

(1) Reference cited above.

(2) *Zeit. f. Physiol. Chem.*, **38**: 84, (1903).

enzymes, as pepsin, trypsin and erepsin, on nucleic acids of animal origin, came to the conclusion that the structure of these bodies was but little disturbed by the action of these enzymes.

Our results bring us to the conclusion that during germination there is a proteolysis of nucleo-proteids with formation of more soluble mobile nucleins and nucleic acids, but not a transformation of the organic phosphorus into the inorganic.

In conclusion, we wish to express to Dr. Jordan, at whose instigation this work was undertaken as preliminary to studies on phosphorus and sulphur metabolism in animals, and to Dr. Van Slyke, our sincere thanks for their constant interest and many helpful suggestions.

COMMENTS.

The results herewith reported are the outcome of a research which was necessarily preliminary to a proposed extended study of the metabolism of phosphorus in the animal body, and the facts presented can but be regarded as an important contribution to our knowledge of the chemistry of foods used by domestic animals. Some of the most important bodies involved in animal nutrition are the proteid compounds containing phosphorus. Such compounds are fundamentally related to the growth of new tissue. Moreover milk and eggs, two human foods of animal origin, important commercially and nutritively, are abundantly supplied with nucleo-proteids (phosphorus-bearing proteids) the source of which, directly or indirectly, is the food of the cow and hen. Several inquiries naturally arise in this connection: What proportions of these bodies are found in feeding stuffs and to what extent do feeding stuffs differ in this respect? Are these compounds synthesized in the animal body or must they be supplied by the food ready for use in growth or in the formation of milk and eggs? Starting with the prevailing understanding that some part of the phosphorus in plant substance exists in inorganic combinations, it was not unreasonable to suppose that the proportions

of organic and inorganic phosphorus would vary widely in different feeding stuffs. Were this the case and assuming that the synthesis of nucleo-proteids could only occur in the plant, it is easy to see how there might be found along this line of inquiry some important distinctions in the value of certain cattle foods when used for specific purposes. These were the hypothetical considerations fundamental to this inquiry.

It was obviously necessary to first inquire concerning the proportion of inorganic phosphorus in cattle foods and the results already reached indicate strongly, as I believe they demonstrate, the absence of any appreciable amounts of inorganic phosphorus in unmodified plant tissue, particularly seeds and grains. This being true, the point of view which was first held is somewhat modified. We must still inquire whether any ration sufficient in quantity would contain an amount of available phosphorus-bearing proteids equal to, or greater than, the amount necessary for the formation of milk or eggs at the usual rate, and, therefore, attention is naturally directed to differences which may exist in such proteids as to availability and function. For instance, such an inquiry as this is pertinent: Does the proportion of easily hydrolyzable phosphorus-bearing proteids in a food have any relation to its efficiency for milk or egg production? It is believed that such inquiries as these are not only profitable but necessary to a solution of certain nutrition problems. We have made, and are still making, great advances in knowledge by the aid of the respiration apparatus, which gives us largely a measure of end results, but equally important are studies of function and relation, which must be carried on, in part at least, through following the transformations and cleavage changes which occur during digestion and assimilation, at the same time that we measure the influence of varying conditions of nutrition upon production.

The earlier methods of experiment and research, such as feeding experiments where the metabolic changes are not followed, must now be recognized as no longer competent to solve the more important fundamental problems related to animal nutrition. There are values and factors which such experiments neither define nor measure and if we are to make real progress we must give more attention to studies of underlying facts.

W. H. JORDAN.

REPORT

OF THE

Horticultural Department.

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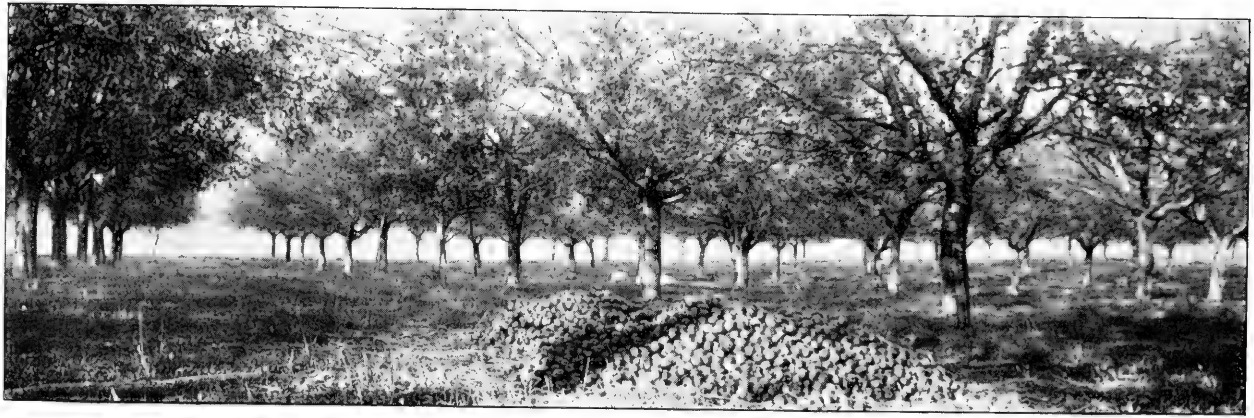

PLATE XIX.—ORCHARD OF MR. T. B. WILSON, WHERE THINNING EXPERIMENTS WERE CONDUCTED.

REPORT OF THE HORTICULTURAL DEPARTMENT.

THINNING APPLES.*

S. A. BEACH.

SUMMARY.

Tests are here reported on thinning apples in June and July during a period of four years. Mature trees of Baldwin, Rhode Island *Greening*[1] and Hubbardston *Nonesuch* were included in the tests. These trees stood in a good commercial orchard. They were well cared for and were all similarly treated except that some had their fruit thinned while others did not. The thinning was usually done when the fruit had grown to about one and one-half inches in diameter.

Observations were made on the effect of thinning upon the color, size and market value of the fruit and upon the amount and regularity of fruit production. Some data were obtained for a comparison of different amounts of thinning but the results are not regarded as conclusive.

Color. When the trees were well filled with fruit, thinning generally improved the color. At harvest time the various hues were heightened and tended to be more brilliant on fruit from thinned

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[1] The name accepted for this variety by the Amer. Prom. Soc. is Rhode Island *Greening*. In this bulletin the common name Greening will hereafter alone be used. The name Hubbardston *Nonesuch* will also be shortened to Hubbardston.

than from corresponding unthinned trees. Where the fruit set sparsely before it was thinned, the thinning had no appreciable influence on its color.

Size. Whenever the trees bore well thinning had the effect of increasing the size of the fruit. This occurred with Baldwin and Hubbardston more often than with Greening, which may be accounted for by the fact that the Greening trees did not carry any crops so heavy as the heaviest crops of Hubbardston and of Baldwin.

Market value. The intrinsic value of the apples from the consumer's standpoint was generally increased by thinning, the thinned fruit being usually superior in size, color and general quality. The thinned fruit, as a rule, was better adapted than the unthinned for making fancy grades, for marketing in boxes, etc. Where such ways of marketing can be advantageously used the thinned fruit should bring an increase in price corresponding to its superiority in real value. But where it must be put upon the ordinary market in barrels there is less chance for the thinned fruit to sell at sufficient advance over the unthinned to pay for thinning, especially if the thinned fruit cannot be furnished in large quantities.

Amount and regularity of fruit production. In these experiments the practice of thinning the fruit did not appear to cause any material change in either the amount or the regularity of fruit production.

Methods of thinning. No exact rule for thinning apples should be laid down. The requirements vary with the different individual trees and with the same tree in different seasons. The amount of thinning should be suited to the conditions as shown by the age and condition of the tree, by the amount of fruit which has set and by the distribution of the fruit on the tree. In thinning apples all wormy and otherwise inferior specimens should first be removed and no more than one fruit from each cluster should be allowed to remain. After this is done, if there is a full set of fruit greater im-

provement in the grade may be expected from thinning to six inches than to four inches apart.

Does it pay to thin apples? The reply of Mr. Wilson, a practical fruit grower in whose orchard these tests were made, is in effect that where there is a general crop of apples, the set full, the chance for small apples great and widespread, it would pay to thin enough to insure good sized fruit; otherwise not, except to protect the tree.

Methods of removing the fruit. No way of jarring or raking off the fruit is advised in thinning apples, since by these methods all grades are removed indiscriminately. Hand work is best. It permits selection of superior, and rejection of all inferior, specimens.

Time to thin. The experiments in thinning apples and other fruits lead to the opinion that early thinning gives best results. Begin with apples within three or four weeks after the fruit sets even if the June drop is not yet completed.

Cost of thinned as compared with unthinned apples. The cost of thinning mature trees which are well loaded should not exceed fifty cents per tree and probably would average less than that. Although a given number of fruits can be thinned faster than an equal number can be picked when ripe, it has required about as much time to thin a tree as it has to harvest the ripe fruit. Thinned apples can be graded more rapidly than an equal amount of unthinned apples. Thinned apples can be handled more economically than unthinned apples because they have proportionately less of those grades which form the least profitable part of the crop, namely, the No. 2's, the drops and the culls.

INTRODUCTION.

Investigations on the general subject of thinning fruit were started at this Station in 1896 and continued for several years thereafter. The work included experiments in commercial orchards with the apple, plum, peach and apricot. A final account with apples is here given. The final report on the experiments in thinning the stone fruits has not yet been prepared. Preliminary reports have been published in the Station Annual Report for 1896 and in addresses before various horticultural societies by Professor C. P. Close and the writer.[1]

OUTLINE OF EXPERIMENTS.

The experiments in thinning apples were carried on for four seasons in one of the orchards of Mr. Thomas B. Wilson, Halls Corners, N. Y. We desire here to express our hearty appreciation of Mr. Wilson's co-operation and interest in the work.

The orchard used for these tests has sustained the reputation of being one of the most productive orchards in one of the good apple-growing sections of Western New York. The trees are generally healthy and in good condition. They are pruned moderately and judiciously and are sprayed regularly and quite thoroughly with bordeaux mixture and some arsenical poison. The orchard is pastured with sheep or hogs and is given barnyard manure from time to time as it seems to be needed. A view of a portion of the trees under experiment is given in Plate XIX.

In 1896 sixteen well-formed, vigorous apple trees in this orchard were selected for experiment. These included eight Baldwin and six Greening trees which had been planted about

[1] Beach, S. A. Thinning Apples. Proc. W. N. Y. Hort. Soc., Rochester, 1897: 75. Beach, S. A. Thinning Fruit. Rept. Mich. Hort. Soc., 1898: 156. Close, C. P. Rept. Utah Farmers' Institutes. 1900: 69.

The results have also been presented in part at various other meetings the proceedings of which have not been published.

twenty-five years, and two Hubbardston trees about forty years old. Trees of the same variety as nearly alike in all respects as could be found were paired for comparison, one of each pair being thinned and the other left without thinning. With the exception of the operations of thinning the fruit, all trees under experiment were in all respects similarly treated. Three ways of thinning were to be tried.

First method.—All wormy, knotty or otherwise undesirable specimens removed and each cluster thinned to one fruit.

Second method.—The same as the first and in addition the fruit thinned to not less than four inches apart.

Third method.—The same as the first and in addition the fruit thinned to not less than six inches apart.

The original intention was to continue the treatment for a series of years on the plan above described in order to learn its effect not only on the fruit of the current season, but on the yield in following years; but because in some seasons there was little fruit or none on some of the trees originally selected for thinning, the plan was modified as hereafter stated.

FIRST METHOD.

The first method, in which imperfect specimens were removed and clusters thinned to one fruit each, was tried on Baldwin only. Two trees which were heavily loaded in 1896 were selected for this experiment. The one on which the thinning was to be done was designated " 13," the other " 14."

Record for 1896.—The thinning was done June 27th, the largest fruits being at that time about one and one-half inches in diameter. The fruit on tree 13 was thinned by taking off all knotty, wormy or otherwise inferior fruit, and all clusters were thinned to one fruit. It took four hours to do the thinning and four for picking, making altogether eight hours. It took five hours to pick the tree that was not thinned. The marketable fruit graded as shown in Table I (p. 299).

From this we see that while the tree which had its fruit thinned gave 16 per ct. less fruit fit for barreling than the unthinned tree, 10 per ct. more of it ranked No. 1, so that it really yielded as

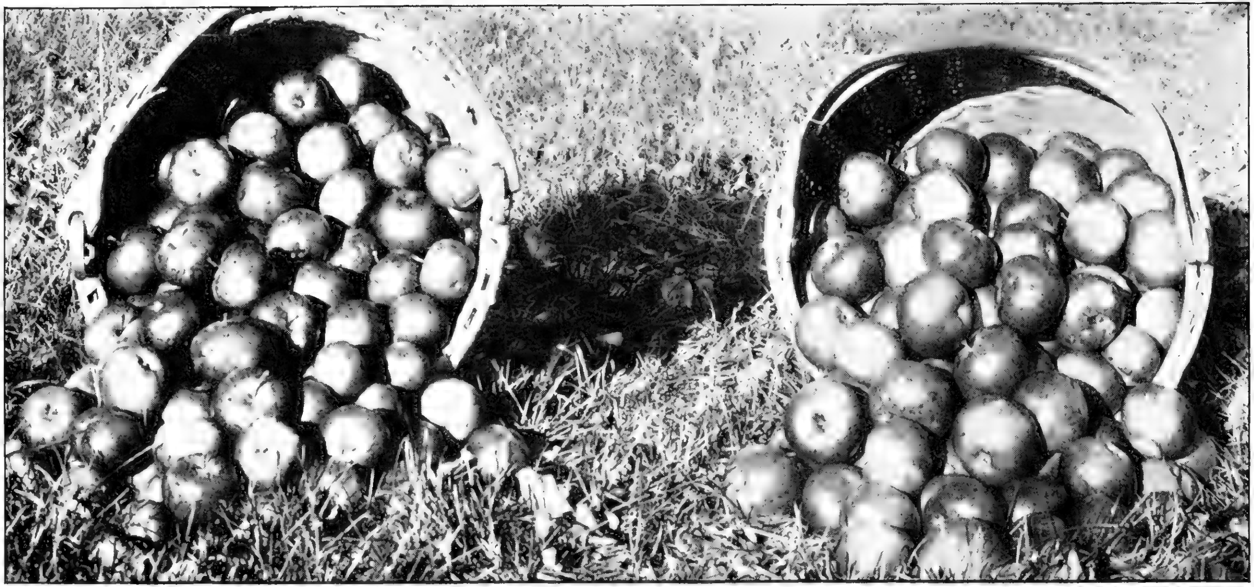
many bushels of No. 1 fruit as did the unthinned tree, without carrying so heavy a burden of inferior fruit. There were about three times as many culls where the fruit was not thinned as there were where it was thinned. The thinned fruit was higher colored and more attractive in appearance than that from the tree which was not thinned. (See also the general statement concerning the thinned fruit in 1896, p. 300.)

Record for 1897.—No fruit was produced by either tree.

Record for 1898.—Trees generally in western New York blossomed full and set well, but apparently because of the frosty nights following the blooming season and the prevalence of cool, damp weather the little fruits lost vitality to such an extent that many of them dropped which under favorable conditions would have matured. The condition of the foliage and the crop prospects were noted for each tree on June 30th. On both trees the foliage was very good for the season of 1898. On tree 13 (thinned) a fair crop remained, and there was enough fruit to permit of thinning on some branches. The crop was scant on the under branches. On tree 14 (unthinned) the prospects for a crop were as good or better than on the other tree. Crop scant on some branches.

Tree 13 was not thinned till July 25th. Time required was one and three-fourths hours. On September 28th an examination of the fruit on these two trees showed that on the thinned tree there was not so much fruit as on the unthinned tree, but it was much larger and better colored. On October 14th the same differences were observed. The fruit on the unthinned tree was decidedly below that on the thinned tree in quality, while on the thinned tree the quality was fine. The grade of the fruit is given in Table I.

Record for 1899.—This was not the "bearing year" for Baldwins in this orchard. Neither of the trees in this experiment had enough fruit to permit of thinning.



Not thinned. Thinned.

Plate XX.—Effect of Thinning on Size of Apples.

SUMMARY FOR FIRST METHOD.

Neither of these trees bore fruit in 1897, and no record of their yield in 1899 was kept because they did not yield enough that year to give an opportunity for thinning the fruit. The results for the years 1896 and 1898 are tabulated below. The yield is stated in bushels. The percentages of barreled fruit marketed in grades 1 and 2 are also given.

TABLE I.—CLUSTERS THINNED TO ONE APPLE; DEFECTIVE AND INFERIOR FRUITS REMOVED.

YIELD PER TREE IN 1896 AND 1898.

Tree.	Treatment.	Year.	Barrel fruit. No 1.		Barrel fruit. No. 2.		Barrel fruit. Total.	Culls.	Drops.	Total yield per tree.
			Bu.	*Per ct.*	*Bu.*	*Per ct.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
13	Thinned to one fruit per cluster.	1896	19.50	70.3	8.25	29.7	27.75	a	a	a
		1898	12.75	85.	2.25	15.	15.	1.5	3	19.5
	Total....	.....	32.25	75.4	10.50	24.6	42.75			
14	Unthinned ...	1896	19.50	60.5	12.75	39.5	32.25	a	a	a
		1898	15.	76.9	4.50	23.1	19.50	3.	4.50	27.
	Total....	.....	34.50	66.66	17.25	33.33	51.75			

a. The drops were inversely proportionate to the yield of fruit fit for barreling, being less on 13 than on 14 and of better quality. The number of bushels of drops and culls was not recorded in 1896.

These results will be considered further in a general discussion following the presentation of report on the other methods of thinning.

SECOND METHOD.

Record for 1896.—The second method, in which all imperfect fruits were removed and all others thinned to not less than four inches apart, was tried on Baldwin and Greening. Three trees of each were thinned and three others of each kind were left unthinned for comparison. The following statement shows the

average yield of marketable fruit per tree and the percentage of it which graded No. 1 or No. 2, as the case may be:

TABLE II.—FRUITS THINNED TO FOUR INCHES APART; INFERIOR AND DEFECTIVE FRUITS REMOVED.

YIELD OF BARREL FRUIT PER TREE, 1896.

Treatment.	Tree Nos.	No. 1.	No. 2.	Barrel fruit.
		Per ct.	*Per ct.*	*Bu.*
Baldwin:				
Thinned	1, 2, 3	80.7	19.3	20.7
Not thinned	4, 5, 6	59.	41.	26.1
Greening:				
Thinned	7, 8, 9	88.	12.	16.7
Not thinned	10, 11, 12	78.5	21.5	15.8

With this method Baldwins gave 26 per ct. less fruit fit for barreling, but 22 per ct. more of it graded No. 1 than did the fruit from the unthinned Baldwins. The unthinned trees gave about three times as many culls as did the thinned trees. That is to say, although the unthinned trees carried over a fourth more fruit, they actually yielded one and one-quarter bushels less No. 1 fruit per tree than did the thinned trees. With the thinned Greenings even a larger proportion of the barrel fruit graded No. 1. They yielded only one bushel more per tree of No. 1 and No. 2 combined, but two and one-third bushels more No. 1 fruit than did the unthinned Greenings. These Greenings were so heavily loaded that it was necessary to prop the branches in 1895. In 1896 they set only a fairly good crop and did not need thinning nearly so much as did the Baldwins, which were overburdened with fruit. The consequence was that in 1896 the Greening fruit was very fine and especially so where it had been thinned.

With all three methods thinning the apples in 1896 gave fruit of quality which was distinctly superior to that of the unthinned fruit. Mr. Wilson estimated that the thinned fruit would bring from 10 per ct. to 15 per ct. more in market than the same grade of corresponding unthinned fruit. The superiority was seen not only in the improvement in each grade, but in the proportionately

larger amount of high grade fruit, in the higher color, the distinctly superior appearance and quality and in the proportionately small amount of drops and culls.

Record for 1897.—The same trees were kept under experiment with the second method in 1897 as in 1896. An examination was made of the trees in the blooming season of 1897. Contrary to expectations, the Baldwins had very little bloom on the trees which were thinned in 1896, nor did they on the unthinned trees. Most of the Greening trees in the orchard bloomed profusely, but those under experiment had 'not nearly so much bloom as the other Greenings. In 1896 the Greening trees which were not under experiment as a rule had a comparatively light crop, while those included under experiment bore well, and for that reason were chosen for the experiment. Of the Greening trees under experiment those which had not been thinned the previous year actually showed somewhat more bloom in 1897 than did the corresponding trees which had been thinned. In this case thinning the fruit in 1896 caused no apparent increase in fruitfulness in 1897.

The growth of fruit was rather slow in the earlier part of 1897 as compared with ordinary seasons, so that the apples were not thinned till July. The object was to postpone the thinning till after the June drop of fruit was over. Notes taken July 1st showed that Baldwin trees 1 and 3 had scarcely any fruit. Tree 2 had more, but not enough to make a fair crop. But little thinning was done on these because only occasionally was the fruit set thickly enough to give a chance for thinning. The largest fruits about this time had a diameter of about one inch. The check Baldwin trees 4, 5 and 6 had scarcely any fruit. The Greening trees 7, 8 and 9 had the fruit thinned July 1st, according to the original plan. At that time they showed hardly fruit enough for a fair crop, while the corresponding check trees 10, 11 and 12 gave promise of a fair to good crop.

With Baldwin the average yield per tree was less than one-half bushel; consequently there were no significant differences in yield between the thinned and the unthinned. Tree 2 gave the largest yield of marketable fruit among the thinned Baldwins, but that was only one-half bushel. Among the unthinned Baldwins

tree 6 gave the largest yield, which was one bushel. The crop of marketable Greenings was between three and four times as large on the unthinned as it was on the thinned trees. It averaged 2.14 bu. per tree where the fruit was thinned and 7.58 bu. per tree where it was unthinned. The amount in each grade is shown below:

TABLE III.—FRUIT THINNED TO FOUR INCHES; DEFECTIVE AND INFERIOR SPECIMENS REMOVED.

YIELD OF BARREL FRUIT PER TREE, 1897.

Tree.	Name.	Treatment.	No. 1.	No. 2.	Total barrel fruit.
			Bu.	*Bu.*	*Bu.*
1	Baldwin	Thinned	*	*	A few apples.
2	"	"	*	*	0.50
3	"	"	*	*	A few apples.
4	"	Unthinned	0	0	0
5	"	"	0	0	0
6	"	"	*	*	1.00
7	Greening	Thinned	2.63	0.37	3.00
8	"	"	2.00	0.43	2.43
9	"	"	1.00	0	1.00
10	"	Unthinned	7.00	1.50	8.50
11	"	"	6.00	0.75	6.75
12	"	"	6.00	1.50	7.50

* Not graded into 1sts and 2nds.

It is not clear that in these cases the thinning resulted in loss. Since the thinned trees had hardly enough fruit for a fair crop before any thinning was done they are not strictly comparable in their yields with the corresponding unthinned trees.

Record for 1898.—With the second method of treatment the same trees were kept under experiment in 1898 as in 1896. Unfavorable weather conditions immediately following the blooming season in 1898 caused the loss of much fruit, as stated more fully on p. 298. On June 30th the trees were examined and it was found that the Baldwin trees 1, 2 and 3, which were to be thinned, gave prospects for only a fair crop, while the corresponding trees which were not to be thinned promised fair to good crops. The Greening trees which were to be thinned gave prospects of scant to fair crops. Those which were to be thinned differed little, on the average, from those which were not. The thinning was

done July 25th. The weight in pounds of the fruit taken off and time required to do the work are stated below:

TABLE IV.—TIME REQUIRED IN THINNING AND AMOUNT OF FRUIT REMOVED.

Name.	No. of tree.	Fruit removed.	Time required.
		Lbs.	*Hrs.*
Baldwin	1	35.	1.33
"	2	40.	1.33
"	3	50.	2.00
Greening	7	13.	0.58
"	8	9.50	0.60
"	9	43.	1.50

The crop was gathered October 13th. The following statement shows the amount of fruit in the various grades:

TABLE V.—FRUIT THINNED TO FOUR INCHES; DEFECTIVE AND INFERIOR SPECIMENS REMOVED.

YIELD PER TREE BY GRADES, 1898.

Name.	Treatment.	Tree No.	Barrel fruit.					Culls.	Drops.	All grades: Total yield.
			No. 1.		No. 2.		Total.			
			Bu.	*Per ct.*	*Bu.*	*Per ct.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Baldwin	Thinned	1	12.00	64.9	6.50	35.1	18.50	3.00	2.00	23.50
"	"	2	12.00	78.7	3.25	21.3	15.25	1.25	1.50	18.00
"	"	3	13.50	72.9	5.00	27.1	18.50	2.50	1.00	22.00
Total			37.00	71.70	14.75	28.3	52.25	6.75	4.50	63.50
Baldwin	Unthinned	4	11.50	55.2	9.00	44.8	20.50	4.50	0 50	22.50
"	"	5	17.25	75 8	5.50	24.2	22.75	4 25	5 00	32.00
"	"	6	13.50	60 0	9.00	40.0	22.50	0.00	1.50	24.00
Total			42.25	64.2	23.50	35.8	65.75	8.75	7.00	81.50
Greening	Thinned	7	5.25	70.0	2.25	30.0	7.50	1.50	0.50	9.50
"	"	8	5.25	67.7	2.50	32.3	7.75	1.75	0.25	9.75
"	"	9	7.50	71.4	3.00	28.6	10.50	1.50	0.50	12.50
Total			18.00	69.9	7.75	30.1	25.75	4.75	1.25	31.75
Greening	Unthinned	10	0.75	75.0	0.25	25.0	1.00	0.00	Few.	1.00
"	"	11	4 00	72.7	1.50	27.3	5.50	1.25	0.50	7.25
"	"	12	6.00	72.8	2.25	27.2	8.25	1.50	0.75	10.50
Total			10.75	72.9	4.00	27.1	14 75	2.75	1.25	18.75

The unthinned Greening trees having less of a crop than those which were thinned produced just as fine fruit as did the thinned trees. The Baldwins of both lots bore much heavier crops than did the Greenings. The thinned Baldwins gave fruit clearly superior in grade, average color and quality to that borne by the unthinned Baldwins, but the total yield was less. Whether the gain in the size, appearance and quality of the thinned fruit would counterbalance in market value the loss in yield from thinning was not decided. It is not easy to determine this definitely where only such small amounts of fruit can be offered to the wholesale trade.

Record for 1899.—Neither the Baldwin nor the Greening trees upon which the experiment of thinning the fruit to four inches apart was being tried bore enough in 1899 to give a chance for thinning the fruit. From other trees in the orchard of the same kinds and of the same age, four each of the Baldwin and the Greening which were carrying good crops of fruit were selected for carrying on this part of the experiment. The Baldwins were given numbers 20, 21, 22 and 23 and the Greenings 24, 25, 26 and 27. Nos. 21, 22, 24 and 26 were thinned and the others were left unthinned for comparison. The thinning was done June 12th and 13th. The largest fruits at this time had a diameter of about three-fourths of an inch. A statement of the time required for thinning follows:

No. 21 Baldwin.............	5 hours.
No. 22 Baldwin.............	3½ hours.
No. 24 Greening............	3 hours.
No. 26 Greening............	2½ hours.

When the crop was gathered it was sorted as usual by putting into No. 1 grade nothing under two and one-half inches in diameter. The following table shows the yield by grades:

TABLE VI.—FRUIT THINNED TO FOUR INCHES—DEFECTIVE AND INFERIOR SPECIMENS REMOVED.

YIELD OF BARREL FRUIT PER TREE, 1899.

Name.	Treatment.	Tree No.	Fruit.					Quality.
			No. 1.		No. 2.		Total m'k't'ble.	
			Bu.	*Per ct.*	*Bu.*	*Per ct.*	*Bu.*	
Baldwin..	Thinned ...	21	9.75	72.2	3.75	27.8	13.5	Good.
	" ...	22	10 5	73.6	3 75	26.4	14.25	Greatly improved.
			20.25	73	7.5	27	27.75	
Baldwin..	Not thinned	23	7.92	53.7	6.75	46.3	14.66	Not good.
	" "	20	8.25	64.7	4.5	35.3	12.75	Not good.
			16.17	58.9	11.25	41.1	27 41	
Greening.	Thinned ...	24	9	75	3	25	12	Fair.
	" ...	26	10.5	82.4	2.25	17 6	12.75	Very fine.
			19.5	78.8	5.25	21.2	24.75	
Greening.	Not thinned	25	15	83.3	3	16.7	18.00	Fair.
	" "	27	9	80.0	2.25	20.0	11.25	Just fair.
			24	82.0	5.25	18.0	29.25	

There was not much difference in the quality of the different lots of Greening, except that on one of the trees which had the fruit thinned the apples were of exceptionally fine quality. The quality of the thinned Baldwin fruit was clearly better than that of the corresponding unthinned fruit and the No. 1's especially were clearly superior to the unthinned No. 1 in color, size and general appearance.

SUMMARY FOR SECOND METHOD.

The results under the second method for the years 1896, 1897, 1898 are tabulated below. The yield is stated in bushels. That portion of the yield which was marketed in barrels is divided into grades 1 and 2 and the percentage is given of barrel fruit in each grade.

The crop was so light that no thinning was done in 1899 on trees 1, 2, 3, 7, 8, 9, which should have been thinned. The crop was likewise light on the corresponding trees which were not to be thinned. The yield of trees 1-12 for 1899 was not recorded, and so does not appear in the table.

TABLE VII.—BALDWIN FRUIT THINNED TO FOUR INCHES; DEFECTIVE AND INFERIOR SPECIMENS REMOVED.

YIELD PER TREE IN BUSHELS—1896-1899.

Tree.	Treatment.	Year.	Barrel fruit. No. 1.		Barrel fruit. No. 2.		Barrel fruit. Total.	Culls.	Drops.	All grades: Total yield.
			Bu.	*Per ct.*	*Bu.*	*Per ct.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1, 2, 3	Thinned....	1896	16.67	80.7	4.	19.3	20.67	**	**	**
"	"	1897	¶	¶	¶	¶	.16	*	*	*
"	"	1898	12.5	71.8	4.92	28.2	17.42	2.25	1.5	21.7
	Total.....	.....	29.07	76.2	8.92	23.8	38.25			
4, 5, 6	Not thinned	1896	15.41	59	10.67	41	26.08	**	**	**
"	" "	1897	¶	¶	¶	¶	.33	*	*	*
"	" "	1898	14.5	63.7	7.83	36.3	21.92	2.92	2.33	27.7
	Total.....	.....	29.5	......	18.5	......	48.33			
21, 22	Thinned....	1899	10.12	72.9	3.75	27.1	13.83	*	*	*
20, 23	Not thinned	1899	8.07	58.9	5.63	41.1	13.69	*	*	*

* Not recorded.

¶ Not graded because the yield was insignificant.

** The drops in each case were relatively greater where no thinning had been done, but the exact yield of culls and drops was not recorded in 1896.

TABLE VIII.—GREENING. FRUIT THINNED TO FOUR INCHES, DEFECTIVE AND INFERIOR SPECIMENS REMOVED.

YIELD PER TREE IN BUSHELS—1896–1899.

Tree.	Treatment.	Year.	Barrel fruit.					Culls.	Drops.	All grades: Total yield.
			No. 1.		No. 2.		Total.			
			Bu.	*Per ct.*	*Bu.*	*Per ct.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
7, 8, 9	Thinned....	1896	14.67	88	2	12	16.67	**	**	*
"	"	1897	1.88	87.5	.27	12.5	2.16	*	*	*
"	"	1898	6	70	2.58	30	8.58	1.58	.42	10.58
	Total.....	.....	22.54	82.3	4.86	17.7	27.40			
10, 11, 12	Not thinned	1896	12.5	78.5	3.25	21.5	15.75	**	**	*
"	" "	1897	6.33	83.5	1.25	16.5	7.58	*	*	*
"	" "	1898	3.58	73	1.33	27	4.92	.92	.42	6.25
	Total.....	.....	22.42	79.4	5.83	20.6	28.25			
24, 26	Thinned....	1899	9.75	78.8	2.63	21.2	12.38	*	*	*
25, 27	Not thinned	1899	12	82.1	2.63	17.9	14.63	*	*	*

* Not recorded.

** The drops were relatively greater where no thinning had been done, but the exact yield of culls and drops was not recorded.

THIRD METHOD.

Record for 1896.—The third method, in which all inferior specimens were removed and all others thinned to not less than six inches apart, was tried with Hubbardston (trees 15, 16) and with Greening (trees 19, 19½). One tree of each kind was thinned while a corresponding tree was left unthinned for comparison The Hubbardston was under experiment from 1896 to 1899 and the Greening from 1897 to 1899. In 1896 25 per ct. less of No. 1 and No. 2 fruit combined was borne by the thinned than by the unthinned tree, but about 17 per ct. more of it graded No. 1.

The unthinned tree gave about three times as many culls as the thinned tree. The superior color and quality of the thinned fruit were especially noticeable. The yield for 1896 is given in the table below.

Record for 1897.—About 21 per ct. more of the crop of the thinned Hubbardston graded No. 1 than was the case with the unthinned Hubbardston, although the total yield of marketable fruit where it was thinned was six bushels less than where it was unthinned. The thinned was the better fruit both of No. 1 and No. 2 apples and was also clearly superior in color and quality.

In 1897 Greening was added to the experiment with the third method of thinning. On the thinned Greening tree the yield of marketable fruit was equal to that on the unthinned tree. The fruit from the two trees showed no difference in color, but the thinned fruit was distinctly superior in size. The yield for 1897 is given in the table below.

Record for 1898.—In July, 1898, the fruit was thinned according to the plan adopted. When the fruit ripened it was evident that the thinned Hubbardston tree was bearing better fruit and had a smaller amount of windfalls than the unthinned tree. The thinned fruit averaged large and well colored, while the unthinned averaged medium size and only fair in color. The yield is shown in the Summary. Neither of the Greening trees bore any fruit.

Record for 1899.—None of the trees under the experiment with the third method of treatment bore enough in 1899 to afford suitable opportunity for thinning the fruit.

SUMMARY FOR THIRD METHOD.

The yield for the trees under the third method of thinning is given in the following table, except for 1899, when the crop was so light that no thinning was done on the trees which were to be thinned. The crop was likewise light in 1899 on the corresponding trees which were not to be thinned.

TABLE IX.—FRUIT THINNED TO SIX INCHES; DEFECTIVE AND INFERIOR SPECIMENS REMOVED.

YIELD PER TREE IN BUSHELS—1896–1898.

Tree.	Variety.	Treatment.	Year.	Barrel fruit.					Culls.	Drops.	All grades: Total yield.
				No. 1.		No. 2.		Total.			
				Bu.	*Per ct.*	*Bu.*	*Per ct.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
15	Hubbardston	Thinned ...	1896	15	71.4	6	28.6	21	**	**	*
"	" "	" ...	1897	15	83.3	3	16.7	18	*	*	*
"	" "	" ...	1898	12.75	74	4.5	26	17.25	2.5	.75	20.75
		Total ..	....	42.75	....	13.5	....	56.25			
16	Hubbardston	Not thinned	1896	14.25	54.3	12	45.7	26.25	**	**	*
"	" "	"	1897	15	62.5	9	37.5	24	*	*	*
"	" "	"	1898	18	75	6	25	24	4.5	6	34.5
		Total ..	....	47.25	....	27	....	74.25			
19	Greening ...	Thinned ...	1897	7.5	79	2	21	9.5	*	*	*
"	" ...	" ...	1898	0		0		0			
		Total ..	....	7.5	....	2					
19½	Greening ...	Not thinned	1897	6	63	3.5	37	9.5	*	*	*
	" ...	"	1898	0		0		0			
		Total ..	....	6	....	3.5					

* Not recorded.

** The drops were relatively greater where no thinning had been done, but the exact yield of drops and culls in 1896 was not recorded.

GENERAL DISCUSSION OF RESULTS.

Now that an account of the experiment of thinning apples has been given, it will be interesting to examine the results and learn what effect thinning apples has had upon:

1. The color of the fruit.
2. The size of the fruit.
3. The market value of the fruit.
4. The amount and regularity of fruit production.

It would also be well to ask

5. Which method of thinning gives best results?
6. Is it profitable to thin apples?

In these experiments no tests of the keeping qualities of the thinned as compared with the unthinned fruit was made. It appears to be the general opinion of those who have had experience in keeping apples that very large or overgrown specimens of apples do not keep so well as those of normal size and firmer texture. This is a subject which is worthy of careful investigation. As a rule consumers show a preference for the larger fruit.

Each of the subjects above mentioned will now be considered.

I. DOES THINNING AFFECT THE COLOR OF THE FRUIT?

With Baldwin under the first method the thinned fruit in 1896 was higher colored than the corresponding unthinned fruit. (See p. 298.) In 1898 it was again better colored than the unthinned Baldwins. (See p. 298.) Baldwin and Greening under the second method of thinning produced fruit of distinctly superior color in 1896. (See p. 300.) Again in 1898 similar results were seen with Baldwin, but not with Greening, because the Greenings bore a very light crop. (See p. 304.) In 1899 similar results were seen (p. 305).

With Hubbardston under the third method the superior color of the thinned fruit in 1896 was especially noticeable (p. 308). In 1897 it was likewise clearly superior in color (p. 308). Again in 1898 the thinned fruit was well colored, while the color of the unthinned fruit was only fair (p. 308). With Greening under the third method but one crop was obtained, viz., that of 1897. The crop was comparatively light and no clear distinction could be made in the color of the two lots of fruit (p. 308).

In general whenever the trees were well loaded with fruit it was found that thinning improved the color of the fruit. Both red and yellow hues were heightened and tended to be more brilliant when the fruit was harvested than they were on the corresponding unthinned fruit. Where the fruit was borne sparsely and really required little thinning, or none at all, the thinning had practically no appreciable influence on the color of the fruit.

2. DOES THINNING AFFECT THE SIZE OF THE FRUIT?

Baldwin fruit in 1896 under the first method averaged much better in size where it was thinned. Of the total fruit fit for barreling it showed 70.3 per ct. No. 1, as compared with 60.5 per ct. of No. 1 where unthinned, and the No. 2 grade showed 29.7 per ct. of thinned fruit as compared with 39.5 per ct. unthinned. There were about three times as many culls of unthinned as of thinned fruit. Besides this it should be noticed that each grade of thinned fruit averaged larger than the corresponding grade of unthinned fruit. (See pp. 297, 298.) In 1898 the thinned Baldwin fruit averaged much larger than the unthinned. The unthinned fruit showed 100 per ct. more culls and 50 per ct. more drops than the thinned. Of the total thinned fruit fit for barreling 85 per ct. graded No. 1 and but 15 per ct. No. 2, while with the unthinned fruit 76.9 per ct. graded No. 1 and 23.1 per ct. No. 2. The thinned fruit also averaged larger in each grade than the unthinned did. (See pp. 298, 299.)

With the second method in 1896 22 per ct. more of the barrel fruit graded No. 1 with the thinned Baldwin than with the unthinned (p. 300). In 1898 the thinned fruit averaged medium size, the unthinned small to medium size. Of the total thinned fruit which was fit for barreling 71.7 per ct. graded No. 1, while of that which was not thinned only 64.2 per ct. graded No. 1 (p. 303).

In 1899 the thinned fruit which was fit for barreling graded 73 per ct. No. 1, while the corresponding unthinned fruit graded but 58.9 per ct. No. 1 (p. 305).

Greenings under test with the second method were only fairly well loaded in 1896, consequently even the unthinned fruit was fine. Of the thinned fruit which was fit for barreling 88 per ct. graded No. 1, while of the corresponding unthinned fruit only 78.5 per ct. graded No. 1 (p. 300). The thinned fruit also averaged larger in each grade than did the unthinned fruit. In 1897 the Greenings did not mature a good crop and the size of the fruit was but little improved by thinning. The thinned fruit showed only about 5 per ct. more in grade No. 1 than the unthinned fruit did. Again in 1898 the Greenings bore but a mod-

erate crop and the thinning did not bring about any increase in size of the fruit. Of the fruit fit for barreling, that which was thinned showed 69.9 per ct. in No. 1 grade, while the unthinned fruit graded 72.9 per ct. No. 1 (p. 303). Similar results were obtained in 1899 (p. 305).

The only method tried with Hubbardston was the third, by which the fruit was thinned to at least six inches apart. In 1896 under this method 71.4 per ct. of the barrel fruit graded No. 1, while only 54.3 per ct. of the corresponding unthinned fruit graded No. 1. Of the total barrel fruit in 1898 from the thinned Hubbardston 74 per ct. graded No. 1, while the unthinned graded 75 per ct. No. 1. The thinned fruit on the average was certainly superior in size and made better grades than the unthinned fruit did. Moreover, the unthinned fruit showed over 60 per ct. more culls and eight times as many drops as did the thinned fruit (pp. 308, 309).

With Greening in 1897 under the third method 79 per ct. of the barrel fruit graded No. 1, while only 63 per ct. of the corresponding unthinned fruit graded No. 1. The thinned fruit was distinctly superior in size, although the crop of both thinned and unthinned fruit was light (pp. 308, 309).

In these tests whenever the trees had a good crop the thinning has had the effect of increasing the size of the fruit. This occurred most often with Baldwin and Hubbardston and not often with Greening. The Greening has a tendency to bear more regularly than the Baldwin and does not usually carry so heavy crops, consequently shows on the average less improvement from thinning than does Baldwin.

3. DOES THINNING APPLES AFFECT THE MARKET VALUE?

So far as the intrinsic value of the fruit influences its market value this question must be answered in the affirmative. The thinned fruit produced in these experiments was generally superior to the corresponding unthinned fruit in size, color and general attractiveness. It was much better adapted than the unthinned fruit for making fancy grades, packing in boxes, etc., and where such methods of marketing can be used to advantage

would undoubtedly sell for a greater advance in price over the unthinned fruit than it would when sold in barrels in the ordinary way. But even when put upon the ordinary market in barrels there are doubtless times when the superior fruit would bring more than the ordinary ruling prices. This would be more apt to occur if the superior fruit could be furnished in large quantities.

This suggests the question whether local associations of apple growers might not be formed for the purpose of grading and marketing their fruit. Well grown, thinned and sprayed apples might be uniformly graded and given the brand of the association. Under good management it would seem that a good reputation might be established for certain superior grades of fruit which could be supplied in quantities sufficiently large to command enough of an advance over ordinary prices to make the enterprise profitable notwithstanding the extra expense of producing such fruit.

The question whether thinning apples may be profitable or not involves other considerations besides the market value of the fruit, and it will be considered separately.

4. HAS THINNING INFLUENCED THE REGULARITY OR THE AMOUNT OF FRUIT PRODUCTION?

When the trees under experiment were paired for comparison those were chosen for each pair which appeared to be about equally productive; but before proceeding to make comparisons as to productiveness it may be well to call attention to the fact that no two trees, even though they be of the same age, same variety, and growing in the same orchard, are exactly alike in respect to regularity and extent of productiveness. These may be modified by the stock upon which the tree is grown, by methods of training, management, etc., but they are also influenced by environment, and no two trees have the same environment. To a certain extent the degree of productiveness is a variety characteristic, but it also seems to be a permanent characteristic of the individual tree, as determined by the various factors above men-

tioned. This is well illustrated in the following account of the individual records of yields of six Greening trees for a period of ten years. Three of these six trees received annual applications of wood ashes, while the other three did not. In all other respects they were all similarly treated. The trees are all of the same age and are located in one of the Station orchards. They were planted in 1850. These trees all bore a full crop in 1896, in which year they showed considerable differences in yield. It is a remarkable fact that they retained practically the same relative rank in productiveness throughout the period of ten years which they showed in 1896.

TABLE X.—RECORD OF YIELD OF INDIVIDUAL GREENING TREES FOR TEN YEARS.

BUSHELS PER ANNUM.

Lot.	Tree.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	Total for 10 yrs.
1	1	0.125	3.67	2.33	17.44	0.78	6.28	0	13.75	4.47	23.41	72.255
1	2	4.50	5.75	4.67	31.96	0.86	12.94	0	27.20	0	37.62	125.500
1	3	1.67	2.25	6.17	27.25	0.54	7.27	0.93	19.04	0	20.46	85.580
2	4	0	0.75	0.83	16 38	0.30	6 86	0	11.99	0	27 87	64 980
2	5	1.125	4.50	5.83	26.32	0.28	8.43	0	16.36	0	21.74	84.585
2	6	5.50	12.50	2.83	31.40	0.44	12.12	0	21.76	0	34.45	121.000
....	....	.....	.....	....	.....	....	(13.17)	0	(23.65)	0	(37.44)	(126 930)

In 1898 tree 6 lost about 8 per ct. of its bearing wood. Its record from 1898 to 1902 should be correspondingly raised to make it comparable with the other trees for those years. The corrected statements appear in parentheses. Using the figures showing the actual yields, the percentages in the following table are obtained. The first column shows for 1896 the percentage which the yield of each tree formed of the total yield of the six trees. The second column in a similar way shows for the ten-year period the percentage which the yield of each tree formed of the total yield of the six trees.

TABLE XI.—SHOWING RELATIVE POSITION OF THE SIX TREES AS TO YIELD IN 1896 AND DURING THE TEN-YEAR PERIOD.

Tree No.	Percentage of total yield.			
	1896.	Relative rank.	10-year period.	Relative rank.
1	12	2	13	2
2	21.2	6	22 6	6
3	18	4	15 4	4
4	11	1	12	1
5	17	3	15 2	3
6	20.8	5	21.8	5

Turn again to the question whether in these tests thinning the fruit has to any considerable degree influenced either the amount or the regularity of the crops produced and examine the results from this standpoint.

Baldwin under the first method, in which fruits were thinned to one in a cluster, bore no fruit in 1897 and too light a crop in 1899 to offer opportunity for thinning. It was very productive in 1896 and moderately so in 1898, thus showing its natural tendency towards biennial crops. The thinning did not seem to modify this tendency. Of the total yield which was fit for the barrel in 1896 the thinned fruit formed 46 per ct. and the unthinned 54 per ct. In 1898 the record showed 43 per ct. and 57 per ct. respectively. It appears, therefore, that during the four years of this test thinning the fruit did not cause the Baldwin to bear more regularly nor more abundantly.

Baldwin under the second method, in which fruits were thinned to at least four inches apart, gave but very little fruit either in 1897 or 1899 on the trees which were under experiment in 1896, viz., trees 1 to 6 (p. 306). It bore well in 1896 and nearly as well in 1898, again showing its natural tendency towards biennial bearing. Of the total fruit fit to barrel the thinned apples in 1896 formed 44 per ct. and the unthinned 56 per ct. In 1898 the figures stood 47 per ct. and 53 per ct. respectively. The relative increase in productiveness of the thinned over the unthinned trees which appears in 1898 under the second method is equaled by the relative decrease which appears under the first method. Under the circumstances neither can be held to be very significant.

The two lots of Greening trees which were placed under the second method of the experiment in 1896 show for the period of three years, 1896, 1897, 1898, practically the same amount of fruit fit for barreling, and in the following year their yields, though not recorded in bushels, were observed to be very light (p. 306). In 1896 the thinned trees produced about a bushel more per tree of the first and second grades combined than the unthinned trees did; in 1897 the unthinned trees averaged nearly five bushels per tree more than the thinned; in 1898 the thinned trees again took the lead, exceeding in yield the unthinned trees by about four bushels per tree; so that for the three years the total yield of first and second grade fruit was very nearly the same for the two lots of trees. As was the case with the Baldwin, these results do not signify that the practice of thinning materially changed either the regularity or the amount of fruit production.

In the Hubbardston we have to deal with a variety which has a tendency to bear more regularly than Baldwin and more abundantly than Greening. Considering only first and second grade fruit, we find that the total yield where the fruit was thinned was 56¼ bushels for the years 1896 to 1898 and 74¼ bushels for the unthinned fruit. In the following year neither the thinned nor the unthinned tree bore enough fruit to give opportunity for thinning, and their yields were not recorded (p. 308). In this pair of trees one was constantly more productive than the other. In order then to learn whether thinning tended to make the yield greater or more regular the amount of the thinned product should be compared year by year with the amount from the unthinned tree. Disregarding the drops and culls, the percentage which each tree bore of the combined yield of both trees, 1 and 2, is shown for each year in the following statement:

TABLE XII.—PERCENTAGE OF THINNED VS. UNTHINNED HUBBARDSTON.

Tree.	Treatment.	Percentage of total yield for the year.		
		1896.	1897.	1898.
		Per ct.	*Per ct.*	*Per ct.*
15	Thinned	44	43	42
16	Not thinned	56	57	58

These results with Hubbardston are in line with those previously noted with Baldwin and Greening in that the practice of thinning the fruit did not appear to cause any material change in either the amount or the regularity of fruit production.

5. WHICH METHOD OF THINNING GIVES BEST RESULTS?

It will be remembered that the original plan called for a comparison of three ways of thinning the apples. In each of these methods all wormy, knotty or otherwise undesirable specimens were removed and all clusters thinned to one fruit. The following statement shows the further requirements, if any, which distinguished the methods:

First method, none.

Second method, no two fruits left less than four inches part.

Third method, no two fruits left less than six inches apart.

Eventually, because some of the work which was planned failed for lack of suitable crops to work with, only one variety, the Baldwin, was tested sufficiently to offer opportunity for comparing one method with another. The following table brings together the records of Baldwin under the first and second methods:

TABLE XIII.—RESULTS WITH FIRST AND SECOND METHODS OF THINNING BALDWIN.

Method.	Trees.	Year.	No. 1 fruit.		No. 2 fruit.		Total yield per tree.	
			Thinned.	Un-thinned.	Thinned.	Un-thinned.	Thinned.	Un-thinned.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Bu.*	*Bu.*
First	13–14	1896	70.3	60.5	29 7	39.5	27.75	32.25
Second ..	1– 6	"	80.7	59	19 3	41	20.67	26.08
First	13–14	1897	0	0	0	0	0	0
Second ..	1– 6	"	¶	¶	¶	¶	0.17	0.33
First	13–14	1898	85	76.9	15	23.1	15	19.5
Second ..	1– 6	"	71.8	63.7	28.2	36 3	17.4	21.9
Second ..	20–23	1899	72.9	58.9	27.1	41.1	13.9	13.7

¶ The fruit was not graded because the yield was insignificant.

The record for 1896 when there was a full crop indicates that the results with the second method were better than were

obtained with the first method. In 1898 with a moderate crop the first method gave the larger amount of No. 1 fruit, but since the crop was lighter than that borne by the trees upon which the second method was tried the fruit was consequently less thickly distributed over the tree and much of it really set thinner than did the fruit on the trees treated by the second method. The fact then that in this instance the fruit grown nominally under the first method was superior in size to that produced under the second method is really in line with the results of the previous season's test, for although the fruit under the first method averaged the larger there was really a less amount of it on the tree than there was on the trees under the second method. It appears, too, that when the fruit is thinned to six inches greater improvement in grade is seen than when it is thinned to four inches. No mathematically exact method can be followed in thinning fruit because the amount of fruit which sets, the distribution of it on the tree and the ability of the tree to bring fruit to perfection vary with the same tree from season to season, as well as with different trees in the same season.

6. IS IT PROFITABLE TO THIN APPLES?

It has been shown that under certain conditions, at least, the size and general quality of apples may be improved by thinning. Whether or not this may be done with profit is a question which cannot be given a definite general answer. In the experiments under consideration where the size and quality of the fruit have been improved by thinning the quantity of marketable fruit has been reduced. If the fruit must be offered on the general market, under existing conditions it is probable that the returns from a thinned crop in many cases would not equal the returns which the crop from the same trees would bring if unthinned. On the other hand when a tree is overloaded and conditions are such that it could not be expected to bring its fruit up to good marketable size it would certainly be good economy to thin the fruit enough to secure good average size.

In these experiments the differences in value between the thinned and the unthinned fruit were not demonstrated accurately

because of the comparatively small amount of fruit under experiment. With the crop of 1896 men of experience in marketing apples estimated that if the thinned fruit could have been furnished in barrels in car lots it would have commanded from 10 per ct. to 15 per ct. higher price than the corresponding grades of the unthinned fruit. But for the practical orchardist who owns his orchard there is another important consideration, namely, the welfare of the trees. Young trees, and with some varieties mature trees also, may be injured by allowing them to bear too heavy a crop of fruit. This may render them more liable to injury from unfavorable climatic conditions, or it may so weaken their vitality that they will not recover normal vigor and productiveness for several years, if they do at all. Then, too, overburdened apple trees are apt to suffer permanent injury from the breaking of large limbs under the excessive weight of fruit. The whole question as to whether it pays under existing conditions to thin fruit in the commercial orchards of western New York is well summed up by Mr. Wilson, in whose orchard these tests were made. In reply to this question he writes: "When there is a general crop of apples and the crop, or set, is very full, so that the chance for small fruit is very great and widespread over the country, I think it would pay to thin to such an extent as to insure good-sized fruit. Aside from this I do not think it would pay, only for the protection of the tree."

METHOD AND TIME FOR THINNING APPLES.

A word may be said as to the opinion of the writer concerning the best method and the best time in the season for thinning apples. No method of jarring or raking off the fruit in thinning is advised because by such methods good, bad and indifferent fruit is indiscriminately taken off. It is best to do the work by hand because intelligent selection can then be made and only the best specimens allowed to remain on the tree.

As to the best time in the season for thinning it may be said that best results seem to be obtained by early thinning. The work should be begun within three or four weeks after the fruit sets, without waiting for the second drop to be completed.

COST OF THINNED AS COMPARED WITH UNTHINNED FRUIT.

In these experiments it has taken from one-half hour to five hours to thin a tree. The time required varies with the size of the tree and the amount of the crop. Usually the thinning together with the gathering of the ripe fruit has taken about twice as much time as it has to gather the corresponding unthinned fruit when ripe. Doubtless many fruit growers have an idea that thinning apples is a more expensive operation than it really is. No time is taken up with handling the fruit when thinning as it is when the ripe fruit is gathered. The fruit which is taken off in thinning is allowed to drop to the ground, whereas the ripe fruit must be put into baskets or other receptacles and carried away. The cost of thinning mature, well-loaded trees ought not to exceed fifty cents per tree and probably would average less than that.

The cost of producing thinned as compared with unthinned apples includes another factor not yet mentioned, and that is the expense of grading the fruit. The thinned apples as a rule can be graded more easily and rapidly than can corresponding unthinned apples. Besides this thinned apples have proportionately less of drops and culls, which increase the cost of handling the crop and which are the least profitable grades of the fruit.

SPRAY MIXTURES AND SPRAY MACHINERY.*

S. A. BEACH, V. A. CLARK AND O. M. TAYLOR.

EXPLANATORY NOTE.

This bulletin has been compiled in larger part by Mr. Clark. Mr. Taylor and the writer of this note have assisted in various ways, especially on practical points concerning spraying and the working of various kinds or parts of spray outfits, also concerning certain material to be included in or excluded from the bulletin. Prof. N. O. Booth collected considerable information concerning individual power spray outfits. Mr. E. T. Casler, Engineer at this Station, furnished the notes on the management of steam engines and boilers, gasoline engines and some other information of a technical nature. Mr. P. J. Parrott, Entomologist of this Station, has given much advice, especially on the subject of insecticides. Mr. F. C. Stewart, Botanist of this Station, has been consulted in regard to the subject of fungicides.

S. A. BEACH.

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* Reprint of Bulletin No. 243.

INTRODUCTION.

The horticultural industries of the State have been placed on a more permanent basis than they were a quarter of a century ago, through the introduction of modern means and methods of fighting injurious insects and plant diseases. This Station has all along taken an active part in the investigations in this line, and has published from time to time information concerning various phases of the subject. Among other things much time has been given to the general study of the preparation of spray mixtures and of the adaptability of various kinds of spraying apparatus to the purposes for which they are intended. This bulletin embodies the results of this study. At the same time much other information has been compiled from various sources, which has however been critically reviewed and interpreted in the light of experience at this Station. Bulletin 170 treats of diseases and insects injurious to fruits, describing them and recommending the best known treatment for each. The bulletin now offered, on spray mixtures and spraying machinery, gives information as to the fungicides and insecticides which are used in spraying, their preparation, and their application. It aims to give an up-to-date account of these subjects. It is suggested that those who are looking to this Station for information of this kind keep this bulletin for reference. The following topics are treated in the order named:

Fungicides and insecticides used in spraying.

The best kind of a spray.

The parts of a spraying outfit, as pump, nozzle, agitator, tank, etc.

The various kinds of spraying outfits, as knapsack, barrel and steam power outfits.

PREPARATIONS FOR SPRAY MIXTURES.

In farm and garden practice various spray mixtures are used against injurious insects and fungi. Those materials which are used to destroy insects are *insecticides;* those used against the fungi are *fungicides.* Those which are noticed in this bulletin are named in the following list:

FUNGICIDES.	INSECTICIDES.
Bordeaux mixture	Scheele's green
Soda bordeaux	Paris green
Soda-lime bordeaux	London purple
Bordeaux dust	Hellebore
Copper sulphate	Arsenite of lime
Eau celeste and soap	Arsenite of soda
Ammoniacal copper carbonate and soap	Arsenate of lead
Potassium sulphide	Arsenite of lead
Iron sulphate and sulphuric acid	Whale-oil soap
Formalin	Resin-lime soap
Corrosive sublimate *(Mercuric chloride)*	Lime-sulphur-salt wash
	Lime-sulphur-soda wash
	Kerosene emulsion
	Crude petroleum and kerosene
	Hydrocyanic acid gas
	Tobacco
	Pyrethrum
	Carbon bisulphide

FUNGICIDES.

BORDEAUX MIXTURE.

Bordeaux mixture is, and will remain, the most important fungicide for general use against fungus diseases of fruits and farm and garden crops, such as apple scab, plum leaf spot, potato mildew, cucumber mildew, etc. There is such a constant demand for information as to how best to make and use bordeaux mixture that this subject is treated more fully than any other in the bulletin.

The essential ingredients for making bordeaux mixture are freshly slaked lime and copper sulphate solution. The fungicidal value lies in the copper.

The lime is added only to prevent injury to foliage and to make the mixture more adhesive and more easily seen after being applied to the foliage. Lime water will not do. A very thin white wash made from lime and water, commonly called milk of lime, is needed. The relative amounts of lime and copper sulphate which are used may be greatly varied because a great excess of lime may be used without injury to foliage, but it is absolutely essential that enough lime be used, or injury to foliage will surely follow. It is not safe to use less than two-thirds as much lime by weight as of the undissolved copper sulphate; that is to say, in the proportion of 2 lbs. of lime to 3 lbs. of copper sulphate.

Excess of lime.—The question will be asked: Why use any excess of lime? The reply is that under certain weather conditions an excess of lime tends to prevent injury to the leaves by bordeaux mixture;[1] as it also does when certain arsenical poisons are added to the bordeaux mixture. Fresh interest was given to the question of the best proportion of lime to copper sulphate because of the widespread injury to bordeaux-sprayed foliage in 1902.

Heretofore two pounds of quicklime have been recommended for neutralizing three pounds of copper sulphate; and this proportion abundantly satisfies the ferrocyanide test. In view of the experience of 1902 it appears that a larger proportion of lime is desirable. Under ordinary circumstances it seems best not to use a greater weight of lime than of copper sulphate since it has been shown that a great excess of the lime tends to render the bordeaux somewhat less efficient against fungi. A thick mixture cannot be sprayed so readily, neither can it be applied so uniformly, as a thinner one. The solid particles do not stay in suspension so well. For instance, in a mixture made according to the normal formula and poured into a glass cylinder 15 inches high, the solids settle between 3 and 4 inches in one hour. In a similar cylinder containing a mixture made with a large

[1]Bulletin No. 220 of this Station, pp. 225–228.

excess of lime the solids settled between 5 and 6 inches in the same time.

Importance of good lime properly slaked.—Prof. L. R. Jones and Mr. W. A. Orton of the Vermont Experiment Station make the following comments on the importance of good lime, properly slaked: "The quality of the lime and the method of slaking it have much influence upon the mixture. Thus, other conditions being equal, a mixture made from a poorly slaked lime settled 19 per ct. [of the height of a column in a glass cylinder]in an hour, while a mixture made from properly slaked lime settled only 8 per ct. in the same time. Lime that had been partially air-slaked gave still poorer results. The lime should be fresh, clean and firm. In slaking, the best results were obtained by adding at first only a small amount of water, preferably hot, and then, as slaking begins, adding cold water in small amounts as needed, never adding much at a time and never allowing the lime to become dry. When too much water is added small lumps of lime are apt to be covered and remain unslaked. When the lime is fully slaked it should be fully diluted by adding water slowly while stirring."

Strength of bordeaux mixture.—The strength of the bordeaux mixture may be wisely varied under different conditions. For ordinary use in apple orchards where a good spray is thoroughly applied a strength of from 1-to-11 or 1-to-10 will usually be satisfactory; for treating the potato a strength of from 1-to-8 or 1-to-7 may well be used. For the very tender foliage of Japan plums and of peaches the mixture, if used at all, may be reduced to 1-to-25 formula. The designations used for the various formulæ are easily understood. For example the 1-to-11 mixture is made by using 1 lb. of copper sulphate for making 11 gallons of bordeaux mixture.

Method of preparation of bordeaux mixture.—It will be seen later that lime may be slaked and thus kept in stock and that a stock solution of copper sulphate may be used; but in order to get a clear un-

derstanding of the subject the simple method of weighing and mixing the ingredients will first be presented.

BORDEAUX MIXTURE, 1-10 FORMULA.

(To make 50 gals.)

Copper sulphate (blue vitriol)	5 pounds.
Quicklime (not slaked)	$3\frac{1}{3}$ to 5 pounds.
Water	50 gallons.

1. Dissolve the 5 lbs. of copper sulphate in any convenient way, in either hot or cold water, using some vessel which the copper sulphate will not corrode. It does not corrode wood, brass or porcelain but acts quickly on iron. Dilute the copper sulphate solution to half or two-thirds of the 50 gallons.

2. Slake the lime and dilute with the remaining part of the 50 gallons of water. It is an advantage to strain the milk of lime to exclude particles which might clog nozzles.

3. Pour the two ingredients together after being thus diluted. *It is important not to mix the lime and copper sulphate solution till after diluting them as much as the formula permits.* If mixed in concentrated form the solid particles of the resulting bordeaux mixture do not stay in suspension well. When the particles hold up well the mixture is better carried for heavy poisons, such as paris green, which may be added for killing insects. Also, such a mixture may be more uniformly distributed than one containing heavier particles. How much less rapidly bordeaux mixture settles when prepared in the improved way, which may be called the new way, than it does when made by mixing concentrated ingredients in the old way will be seen at once by comparing A and B in Figs. 1, 2 and 3, A having been made by mixing concentrated solutions and B by mixing dilute solutions. Fig. 1 shows the mixture just made and Figs. 2 and 3 the same mixtures 20 minutes and one hour later, respectively.

Bordeaux mixture made from stock solutions.—Where large areas are to be sprayed it is convenient to make the bordeaux mixture from

a stock solution of copper sulphate. A saturated solution, in which the water contains all of the copper sulphate which it will take up, holds about 3 pounds of the copper sulphate to the gallon (49 ozs. at 59° F.). For a 5 lb. formula 1⅔ gallons of such solution would be taken.

Some hold that it is more convenient to make a stock solution which contains 2 lbs. per gallon. Such a solution gradually becomes stronger as evaporation takes place, whereas the saturated solution is always as strong as it can be made.

To dissolve copper sulphate in large quantities in cold water, hang the sulphate in a coarse sack in the top of the water. Leave for a day or more if necessary.

Stock lime paste.—Several ways are known whereby the bordeaux mixture may be tested to find out whether enough lime has been added to unite with all of the copper sulphate, thus avoiding the necessity for weighing the lime. This permits of the slaking of considerable quantities of lime at one time. The lime may then be kept in excellent condition for some time if covered with water to exclude the air.

Ferrocyanide of potassium test.—The test most commonly used for determining whether or not enough lime has been put into the bordeaux mixture to combine with all of the copper sulphate is the ferrocyanide of potassium test, commonly called the "ferrocyanide" test.

Potassium ferrocyanide is also called yellow prussiate of potash. It is a very poisonous yellow salt which dissolves readily in water. A few cents' worth dissolved in about ten times its bulk of water will ordinarily last through the season. In using this test fill the spray tank half to two-thirds full of the copper sulphate solution, then pour in the milk and lime. Stir the mixture thoroughly and add a drop of the potassium ferrocyanide. If enough lime has been added the drop will not change color when it strikes the mixture, otherwise it

will immediately change to a dark, reddish-brown color. More lime must then be added until the ferrocyanide does not produce the reddish brown color. Even after the test shows no color more lime should be added so as to be sure that all of the copper is precipitated, for in case the mixture has not been thoroughly stirred some of the copper may still remain in solution in the bottom of the barrel while the test shows no color at the surface.

If the formula calls for a quantity of lime equal to the copper sulphate in weight, a half more lime than is required to satisfy the ferrocyanide test should be added to the mixture. Suppose for example one wished to take 6 pounds of copper sulphate and 6 pounds of lime with 60 gallons of water to make 60 gallons of bordeaux mixture and to use the ferrocyanide test. When the test first shows that enough lime is present to combine with all of the copper sulphate the mixture will contain somewhat less than 4 pounds of lime. To complete the mixture according to the 6–6–60 formula requires the addition of half as much lime as has already been used, that is to say, it requires 2 pounds more of lime, or the equivalent amount of the lime paste.

Mixing tanks.—It is convenient to have special tanks for mixing the bordeaux. Thus the tank for the lime may be placed so that its contents may be drawn off into the tank in which the copper sulphate solution is put and in which the mixture is made. This tank may likewise be elevated so that the prepared bordeaux mixture may be drawn off into the spray tank. By this arrangement it is possible to avoid the necessity of dipping and lifting the mixture. If these tanks are so located with relation to the water supply that the water may be run into the lime tank it is possible to avoid the necessity of dipping and lifting every gallon of mixture that goes into the spray tank; the lime may also be strained both when it is put into the lime vat and when it is run from there into the bordeaux vat, which is an advantage.

SODA BORDEAUX AND SODA LIME BORDEAUX.

Experiments with the soda bordeaux mixture have been in progress for several years at the New Jersey Experiment Station. Tests have also been made of this mixture at the Ohio Station, together with field tests in some of the grape districts of that State. Soda bordeaux is made by adding caustic soda to a solution of copper sulphate until the mixture becomes exactly neutralized. Much care must be taken not to have an excess of either ingredient. In the hands of fruit growers this mixture has sometimes resulted disastrously to the foliage because of the presence of an excess of one or the other ingredient in the mixture. It is not surprising that some fruit growers find difficulty in bringing soda bordeaux to exact neutrality. On account of the difficulty, Dr. Halsted of the New Jersey Experiment Station, has recommended that the soda be added to the copper sulphate solution until it approaches a neutral condition, and that the preparation of the mixture be then completed by adding small amounts of milk of lime. No experiments with either soda bordeaux or soda-lime bordeaux have been made at this Station, and no literature has been published. Publications on this subject can be obtained from the New Jersey and Ohio Stations, and for detailed information with regard to this mixture the reader is referred to the Botanists at the above mentioned Stations.

BORDEAUX DUST OR DRY BORDEAUX MIXTURE.

The utility of the so-called " dust sprays " will not be discussed here but will be touched upon in presenting the subject of " dust sprayers." Bordeaux mixture is prepared for use in dust sprayers in two principal ways:

1. The lime is slaked by pouring over it the copper sulphate in strong solution.

2. The freshly slaked lime in the form of thin paste is mixed with the strong copper sulphate solution.

This latter appears to give the best powder. The operation is well described by Dr. Bird in Bulletin 60 of the Missouri Station. His directions are here given:

1. "Break up into small lumps about seventy or eighty pounds of quicklime and spread it out so that it will become air-slaked. When slaked and perfectly dry sift it through the fine sieve (100 meshes).

2. "Completely dissolve four pounds of copper sulphate in two and a half gallons of water. The easiest way is to suspend the sulphate in a coarse bag just below the surface of the water until it is dissolved.

3. "Pour gradually two and a half gallons of water over four pounds of *good* quicklime in such a manner as to slake it to the finest powder and give a good milk of lime solution; let it cool.

4. "Put sixty pounds of the sifted, air-slaked lime into a shallow box, one in which the material can be well worked with a hoe or shovel.

5. "Pour the well-stirred milk of lime and the copper sulphate solution *at the same time* into a third vessel and stir until the whole is thoroughly mixed. It will have a deep blue color and be thick. This is so finely divided that it will remain in suspension for hours.

6. "Pour this immediately into a double flour-bag filter and squeeze out most of the water. [This consists of two close-woven, cotton flour bags, one slipped inside the other, with which the blue material is filtered.]

7. "Empty this wet, blue material at once (*do not let it dry*) into the sixty pounds of air-slaked lime and work it up so that it will be well distributed. If the resulting mixture is too moist add more air-slaked lime.

8. "Rub this through a *coarse* sieve (25 mesh) *while still somewhat damp,* mix thoroughly and spread out to dry.

9. "When perfectly dry sift it through a fine sieve (100 mesh), crushing all lumps. All of this can readily be made to go through

the fine sieve, except the small amount of sand which may be in the four pounds of quicklime. Mix so that the blue copper compound will be prefectly evenly distributed throughout the whole mass."

Bordeaux dust may also be prepared by making a standard bordeaux mixture and allowing it to stand until the blue precipitate has settled. The clear water is then poured off and the blue precipitate thoroughly dried and ground between millstones to a fine powder. A similar article is offered in trade under various names.

According to the Vermont Experiment Station these dry mixtures are much inferior to the standard mixture properly made and promptly applied—so much so that their use is not to be recommended. In experiments in which they were applied wet, these powders settled very rapidly; and when applied dry, even in most liberal amounts, they were even less effective than were the same powders in wet form.

Some have reported good results from the use of bordeaux dust against the ripe rot of stone fruits while others have had opposite results. The use of the bordeaux dust on ripening fruits is still in the experimental stage. It is not yet to be definitely recommended.

COPPER SULPHATE SOLUTION.

Copper sulphate	1 pound.
Water	15–25 gallons.

This solution is sometimes used as a winter spray. It must be applied only before the buds start, as it is injurious to foliage. The objections to it are that it is not easily seen on the tree and it is easily washed off by rains. On the whole, bordeaux mixture is generally to be preferred.

A much weaker solution, consisting of 1 pound of copper sulphate to 200–300 gallons of water, is sometimes recommended as a substitute for ammoniacal copper carbonate in spraying ripening fruit, especially peaches and plums. It appears that this solution cannot

be made strong enough to be efficient against fungi without being injurious to foliage. For the purposes for which this is indicated we prefer eau celeste and soap or ammoniacal copper carbonate and soap or the soda-lime bordeaux. (See p. 329.)

See also under "dry bordeaux dust" (p. 329).

EAU CELESTE AND SOAP.

Copper sulphate	1 pound.
Ammonia (26° Beaumé)	3 pints.
Soap	1 pound.
Water	50 gallons.

Dissolve the copper sulphate in 40 gallons of water and add the ammonia. In another vessel dissolve the soap in 10 gallons of water. mix the two solutions. This is not so effective a treatment as bordeaux mixture. It has proved beneficial for spraying when fruit is ripening and discoloration by a spray mixture is undesirable.

AMMONIACAL COPPER CARBONATE AND SOAP.

Copper carbonate	6 ounces.
Ammonia (26° Beaumé)	about 3 pints.
Soap	1 pound.
Water	50 gallons.

Dissolve the copper carbonate in the ammonia, somewhat diluted with water, using no more ammonia than is necessary barely to dissolve the copper carbonate. Put this into 40 gallons of water. Dissolve the soap and add to the solution of copper carbonate. The solution loses strength on standing in open vessels but may be kept indefinitely in stoppered bottles.

Copper carbonate may be made at home as follows: "Dissolve 10 pounds copper sulphate in 10 gallons of water, also 12 pounds carbonate of soda in the same quantity of water. When cool, mix the two solutions slowly, stirring well. Allow the mixture to stand twelve hours and settle, after which pour off the liquid. Add the same quantity of water as before, stir and allow to stand the same

length of time. Repeat the operation, after which drain and dry the blue powder, which is copper carbonate."

POTASSIUM SULPHIDE SOLUTION.

Potassium sulphide	1 ounce.
Water	2 gallons.

This solution loses strength by standing and must be used immediately. The potassium sulphide should be kept in a well-stoppered bottle. Valuable in fighting mildew, especially the gooseberry mildew.

IRON SULPHATE AND SULPHURIC ACID SOLUTION.

Iron sulphate (copperas)	110 pounds.
Sulphuric acid	1 quart.
Hot water	26 gallons.

Add the acid to the copperas and pour on the water. Use when fresh. To be used only as a wash before the buds swell, applied with a brush or sponge. Chiefly valuable for grape anthracnose. Very caustic. Care should be used not to get it on the hands or clothes. Wear rubber gloves when applying it.

FORMALIN SOLUTION.

For potato scab:

Formalin	1 pint (1 pound).
Water	30 gallons.

Soak the seed potatoes in the liquid for about two hours.

For grain smut:

Formalin	1 pint (1 pound).
Water	50 gallons.

Thoroughly sprinkle the grain, stirring during the process. Leave it in piles for several hours.

CORROSIVE SUBLIMATE SOLUTION.

Corrosive sublimate	1 ounce.
Water	7 gallons.

For potato scab. Soak seed potatoes 1½ hours. This should be done several weeks before planting. This treatment is now generally supplanted by the formalin treatment.

INSECTICIDES.

Insecticides when viewed from the way in which they cause the death of insects fall into two general classes: (1) Poisons used against insects having biting mouth parts and (2) contact remedies used against insects having sucking mouth parts. These are conveniently grouped as follows:

POISONS.

I. *Standard remedies:*
- Scheele's green
- Paris green
- London purple
- Hellebore

II. *Commercial substitutes:*
- Paragrene
- Green arsenoid
- Green arsenite
- Pink arsenoid
- Laurel green
- Arsenate of lead
- Disparene

III. *Home-made remedies:*
- Taft's arsenite of lime
- Kedzie's arsenite of soda
- Arsenate of lead
- Arsenite of lead

CONTACT REMEDIES.

I. *Standard:*
- Tobacco
- Pyrethrum
- Kerosene emulsion
- Whale-oil soap
- Lime-sulphur-salt wash
- Hydrocyanic acid gas
- Carbon bisulphide

II. *Proprietary:*
- Slug shot
- Derror's fluid, etc.

Some of the more important of these are here discussed:

SCHEELE'S GREEN OR GREEN ARSENITE OF COPPER.

One serious drawback to the use of paris green is that it settles very rapidly when mixed with water and unless the pump is provided with the best of agitators it is difficult to maintain a spray in which the amount of the poison is constant. Scheele's green is superior to paris green in this respect as it is in the form of a very fine powder which stays in suspension much longer than paris green. On comparing mixtures of the same strength it was found that

while paris green settled to the bottom of the vessel in about five minutes, the green arsenite remained in suspension over two hours. It is used in the same proportions as paris green, one pound to from 150 to 200 gallons of water, using lime to prevent injury to foliage, or it may be added to bordeaux mixture in the same proportions.

Green arsenite is a name given to a commercial substitute for Scheele's green. It is variable in composition and hence less reliable than that poison.

PARIS GREEN.

Paris green may be applied either in the dry form or as a spray. When the spray is used the paris green may be combined with bordeaux mixture, or it may be applied mixed with water. In either case the same amount of poison is used. For pomaceous fruits, such as apples and pears, one to two pounds of paris green to one hundred and fifty gallons of water is recommended. Many are using much more than this amount but the more the strength is increased the greater the danger of injuring the foliage. For stone fruits the mixture should be weaker, using one pound of paris green to two hundred and fifty or three hundred gallons of water. When used with water, two pounds of freshly slaked lime must be added for each pound of paris green, to prevent injury to the foliage.

Where adulteration is suspected, if some of the poison is crushed between two pieces of window glass or between the thumb and finger, oftentimes some small lumps will be found white inside, showing that some adulterant has been used. The ammonia test, which is very simple though not infallible, may also be used. Pure paris green will readily dissolve in ammonia and the solution will be of a deep blue color. If there is any residue left, or if the solution does not become blue at once, adulteration may be suspected.

The law in this State fixing the standard of paris green has largely stopped the practice of adulteration, and this poison as sold here may be regarded as reliable. For information regarding the purity

of brands of paris green which are on sale in this State consult bulletins of this Station in which analyses of such brands are published.

Paris green dissolved in ammonia.—Some fruit growers make a practice of dissolving all the paris green that they use, thinking that the poison will be more effectual in a liquid state. This might work very well if it were not for the fact that lime must be added to the paris green solution in order that injury to the foliage may be prevented. When lime sufficient to neutralize the corrosive action of the poison has been added the paris green is at once precipitated so that it is in a form similar to what it was before it was dissolved. Thus it will be seen that nothing is gained by the operation, but on the other hand a considerable expense has been incurred since it takes about a pint of strong ammonia to dissolve a pound of paris green.

LONDON PURPLE.

London purple is a by-product in the manufacture of analine dyes. It is an arsenite of lime. Compared with paris green it is a finer powder, remains better in suspension, and is also cheaper. But it is variable in composition, which greatly detracts from its value. The directions for using paris green apply to this poison.

HELLEBORE.

This is a yellowish powder, obtained by pulverizing the roots of the white hellebore plant. It is used as a substitute for the arsenical poisons, especially for plants bearing fruit that will soon be used for food. It is especially recommended for the treatment of the larvæ of saw flies, as the cherry slug, currant and raspberry worms. It may be used dry, diluted with five parts of flour or air-slaked lime, or wet, using 1 ounce to 3 gallons of water.

ARSENITE OF LIME. TAFT FORMULA.

The demand for a cheaper poison than paris green has led to the use of white arsenic as a substitute. Arsenic must be used in com-

bination with other substances which will render it insoluble, since it is very injurious to foliage when in a soluble form. It will be seen then that white arsenic and water or white arsenic dissolved in sal-soda and water without lime are unsafe combinations to use. Arsenite of lime is a safe form in which to use arsenic since it does not dissolve in water. There are two methods of preparing arsenite of lime as follows:

White arsenic	1 pound.
Freshly slaked lime	2 pounds.
Water	2 gallons.

Boil for twenty minutes or more, then dilute with 400 gallons of water. To insure having a safe spray add 2 pounds of lime paste to every 50 gallons of spray mixture. This formula is not considered as reliable as the one given below since it is difficult to tell when all of the arsenic is dissolved and combined with the lime and if prepared in large quantities the arsenite of lime will gradually settle into a compact mass that will not readily mix with water.

ARSENITE OF SODA. KEDZIE FORMULA.

White arsenic	2 pounds.
Sal-soda	8 pounds.
Water	2 gallons.

Boil until the arsenic is all dissolved, which will take about fifteen minutes. Replace the water that has been lost in boiling as otherwise some of the material will crystallize upon cooling; then place in an earthen vessel where it can be kept as a stock solution. One pint of this stock solution is equivalent to four ounces of paris green and is used in the same way; that is, one pint of the stock solution, two pounds of freshly slaked lime and 45 gallons of water, or one pint of the stock solution to 45 gallons of bordeaux mixture. It must not be used alone, but lime must be added. It then forms arsenite of lime.

It is very important that the vessels that are used in making or storing this and the preceding poison be plainly labeled and never used for any other purpose.

ARSENATE OF LEAD. (1)

Acetate of lead	11 ounces.
Arsenate of soda	4 ounces.
Water	50 gallons.

Dissolve the acetate of lead in 2 quarts of water and the arsenate of soda separately in another 2 quarts. Pour the solutions together into the spraying tank containing the required amount of water. There is formed a white precipitate of arsenate of lead. To make one pound of arsenate of lead, there are required twenty-four ounces of acetate of lead and ten ounces of arsenate of soda. In preparing this poison purchase only first class chemicals. High-grade crystallized acetate of lead contains about 58.8 per ct. available lead oxide. Arsenate of soda should not have more than two or three per ct. of chloride.

Arsenate of lead is less liable to injure the foliage than is paris green and on account of its color it shows plainly where it has been applied. It remains in suspension well and there is no difficulty in applying it at uniform strength.

Arsenate of lead is also handled in trade as a proprietary article under the name of Disparene. In considerable quantities it can be prepared more cheaply than it can be purchased, but in small lots the ready-made material is the cheaper.

The following formula may also be used:

ARSENATE OF LEAD. (2.)

Nitrate of lead	10 ounces.
Arsenate of soda	5 ounces.
Water	50 gallons.

This is prepared in the same manner as preceding formula.

ARSENITE OF LEAD.

Acetate of lead	4 pounds.
Arsenite of soda	12 ounces.
Water	50 gallons.

This is prepared in the same manner as arsenate of lead.

WHALE OIL SOAP.

This is a rather inexpensive spray for elongated scales, plant lice and other soft-bodied insects. It may be used on foliage at the rate of 1 pound in 7 gallons of water. It is an expensive remedy for San José scale but is convenient for the treatment of a few trees. For this purpose use during the dormant season at the rate of 2 pounds in one gallon of water. Use only best quality of soap.

RESIN-LIME SOAP.

Pulverized resin	5 pounds.
Concentrated lye	1 pound.
Fish oil, or any cheap animal oil except tallow	1 pint.
Water	5 gallons.

Place oil, resin and a gallon of water in an iron kettle and heat until resin is softened; add lye solution made as for hard soap; stir thoroughly; add remainder of water and boil about two hours, or until the mixture will unite with cold water making a clear, amber-colored liquid. If the mixture has boiled away too much, add sufficient boiling water to make 5 gallons.

For use, 1 gallon of this stock solution is diluted with 16 gallons of water and afterward 3 gallons of milk of lime or whitewash added. The resin mixture is in reality a liquid soap and the addition of the lime turns it to a hard soap which remains suspended in the water in minute particles. The poison, ¼ pound of paris green or other arsenite, is then added, and the particles of poison adhere to the finely divided soap particles and are thus distributed throughout the mixture in minute and uniform quantities. The soap solution is very adhesive and thus a thin film of poison is made to stick to

every part of the leaf which is touched by the spray. Upon cabbage and cauliflower the use of this mixture requires a strongly made pump of considerable power. The nozzles must be guided by hand to cover thoroughly all parts of the plants.

This material can no doubt be used to advantage in combination with bordeaux mixture for use on plants that have leaves not easily wetted.

LIME-SULPHUR-SALT WASH.

Lime	15 pounds.
Sulphur	15 pounds.
Salt	15 pounds.
Water	50 gallons.

Boil one hour. A detailed account of methods of preparing and applying this wash and of some results obtained will be published by this Station early in the spring of 1904.

LIME-SULPHUR-SODA WASH.

Quicklime	30 pounds.
Sulphur, ground	15 pounds.
Caustic soda	4 to 6 pounds.
Water	50 gallons.

Experiments in making a lime-sulphur wash by using caustic soda to avoid the necessity of boiling have given some promising results. This wash is intended to take the place of the ordinary lime sulphur-salt wash. Methods of preparing and applying this wash will be published by this Station early in the spring of 1904.

KEROSENE EMULSION.

Kerosene	2 gallons.
Whale oil soap	½ pound.
Water	1 gallon.

Heat the soap and water together, and when boiling hot remove from near the fire and add two gallons of kerosene. The whole is now thoroughly mixed by pumping continuously through a small force pump for about five minutes. Mix until the ingredients form

a creamy mass that becomes thick when cool and from which the oil does not separate. For summer use dilute with 15 to 20 parts of water for plant lice and soft-bodied insects; for plant bugs, larvæ and beetles dilute 1 part with 7 to 9 parts of water. Some venture to use it as strong as 1 to 5.

When used as a winter treatment it may be applied as strong as one part of the mixture to four parts of water. After the stock emulsion becomes cold it hardens so that it is necessary to melt it before it can be successfully diluted. It takes fire very readily, so it is always best to have the fire out of doors when making the emulsion.

Do not apply the mixture with pumps that have rubber balls for valves. Replace the balls with marbles as the kerosene soon destroys rubber. There is a large amount of whale oil soap of poor quality on the market which accounts for trouble that some people experience in forming the emulsion. Only the better grades of whale oil soap should be used.

CRUDE PETROLEUM AND KEROSENE.

Crude petroleum and kerosene may be applied clear or emulsified at the rate of 40 per ct. oil and 60 per ct. water. They are convenient but dangerous sprays and should be used only by experienced sprayers. They may be applied to apple, pear and plum trees but not to peach trees. Experiments with them are recorded in Bulletins 194, 202 and 213 of this Station.

HYDROCYANIC ACID GAS.

Fused cyanide of potassium	1 ounce.
Sulphuric acid	1 ounce.
Water	3 ounces.

This gas must be confined in a gas-tight room or other receptacle, both to secure efficiency against insects and to prevent injury to other forms of life. It is exceedingly poisonous.

Pour the water into a glass or glazed earthenware dish and add

the sulphuric acid. After having placed the receptacle in proper position add the cyanide. This amount is sufficient for 150 cubic feet of space. The operator should take great care not to inhale any of the fumes. The treatment is efficient. It is especially adapted for greenhouse and nursery fumigation. For further details see Bulletin 202 of this Station.

TOBACCO.

Tobacco stems	1 pound.
Water	2 gallons.

Boil the stems and strain the liquid. Add water to make the decoction up to 2 gallons. The efficiency of tobacco water may be increased by stirring in 1 pound of whale-oil soap to each 50 gallons. Tobacco is valuable against plant lice and woolly aphis.

PYRETHRUM.

For use as spray:

Pyrethrum	1 ounce.
Water	3 gallons.

For use in dry form:

Pyrethrum	1 part.
Flour	2 to 3 parts.

This is a powerful contact poison, especially adapted for fighting lice and many small insects. It is not poisonous to the higher animals or to man.

CARBON BISULPHIDE.

This is used against root-inhabiting insects, such as plant lice, woolly aphis and ants, and against wire-worms, beetles, weevils, etc., affecting stored grains. The fumes destroy the insects, and should be confined to secure best results. For bin pests use 1 pound of carbon bisulphide for each 1,000 cubic feet of space. Remember that the fumes are explosive. Do not bring fire near them.

COMMERCIAL INSECTICIDES.

Some commercial substitutes for the standard poisons are: Paragrene, Green Arsenoid, Green Arsenite, Pink Arsenoid, Laurel Green, Arsenate of Lead and Disparene.

These are sometimes used in preference to the poisons previously mentioned. But before adopting any one of them for exclusive use, it is advised that a competent chemist be consulted.

Among the proprietary contact poisons are Slug Shot, Derror's Fluid, etc. These are comparatively costly. They possess no advantage over standard remedies.

WHAT IS THE MOST DESIRABLE SPRAY AND HOW OBTAINED?

In applying bordeaux mixture or other fungicide to any foliage it is evident that perfect work is done when the spray covers the leaf surface most completely and permanently. The same is true of spraying with arsenical insecticides or other insecticides which are applied to the leaf for the purpose of killing insects by poisoning their food. Experience shows that with liquid preparations this may be best accomplished when the liquid is broken into so fine a spray that it will rest upon the leaf in mist-like particles and dry in that position. In practical operations, before every leaf becomes covered in this way the liquid will often drip from some of the leaves. Nevertheless, the aim should be to cover every leaf in the manner described and in so doing to avoid as much as possible making any of the foliage so wet that it will drip. *Any portion of the leaf surface which is not covered with the spray mixture evidently remains unprotected from the attacks of the fungi.* Not only may a much better spray be applied with a perfect mist than with a coarse spray but it may also be applied with less expense of time and of material.

It is beyond question that a pressure of from 100 to 120 pounds gives a finer mist than can be obtained with the same apparatus under

a pressure of from 70 pounds to 80 pounds. Herein lies one advantage of so-called "power" sprayers. With these a greater pressure may easily be maintained than it is practicable to keep up with any hand pump.

The character of the spray is determined not only by the amount of pressure but also by the kind of nozzle. No form of nozzle has been devised which gives a better spray than those constructed on the principle of the Vermorel. With such nozzles a fair spray may be had with even 50 pounds pressure. Much profitable spraying has been done with them with no higher pressure than from 50 to 60 pounds. Nevertheless with double that pressure a much better spray is obtained.

There are other forms of nozzles with which a spray may be thrown to a greater distance than can be done with nozzles of the Vermorel type. On this account they may sometimes be used to advantage but generally speaking it is not good economy to use them. It is better to use a nozzle made on the same principle as the Vermorel and to devise some way of getting it close to the foliage which is to be reached by the spray. This may be done by extension pipes or rods or by putting towers on the spraying rig from which the high tree tops may be reached, or by a combination of both methods.

For further discussion on these points see under Nozzles, Extension Rods and Towers.

SPRAY MACHINERY.

TRADE CATALOGUES CONSULTED.

In preparing this bulletin we desired to have before us accounts of the most recent devices in spraying apparatus and therefore sent requests to many manufacturers for information concerning their

lines of spraying apparatus. In return printed matter was received from the firms named below:

E. C. Brown & Co., Rochester, N. Y.
Dust Sprayer Mfg. Co., 510 Broadway, Kansas City, Mo.
Deming Co., Salem, O.
W. & B. Douglas, Middletown, Conn.
Field Force Pump Co., Elmira, N. Y.
Friend Mfg. Co., Gasport, N. Y.
J. F. Gaylord, Catskill, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Spray Pump Mfg. Co., Detroit, Mich.
H. W. Henry, LaPorte, Ind.
Hillis Dust Spray Mfg. Co., McFall, Mo.
Leggett & Bros., New York.
J. J. Kiser, Stanberry, Mo.
Morrill & Morley, Benton Harbor, Mich.
F. E. Myers & Bro., Ashland, O.
Niagara Spraying Co., Middleport, N. Y.
Pierce-Loop Sprayer Co., Northeast, Pa.
Rochester Machine Tool Works, Ltd., Rochester, N. Y.
Rippley Hardware Co., Grafton, Ill.
D. B. Smith & Co., Utica, N. Y.
Spramotor Co., London, Ont., and Buffalo, N. Y.
Wm. Stahl, Quincy, Ill.
Wallace Machinery Co., Champaign, Ill.
R. B. Williamson, Clifton Springs, N. Y.

THE ELEMENTS OF A SPRAYING OUTFIT.

In discussing the subject of spraying outfits it will be convenient to consider the elements of which such outfits may consist under the separate headings of pumps, nozzles, agitators, extension rods, hose, strainers or "separators," crop-sprayer attachments, towers, trucks and tanks.

PUMPS.

A spray pump has certain peculiarities which distinguish it from pumps in general. The most important one is that the working parts should be entirely of brass or certain kinds of bronze or some other substance which the spray liquids do not corrode, or should at least be covered with such metal, since bordeaux mixture attacks the more

commonly used metals of ordinary pumps. Neither should leather or rubber valves be used. This is important. The valve used in the better class of spray pumps is a brass valve ground to fit its seat perfectly. Some pumps are made with removable brass lining, permitting the quick replacing of a worn lining with a new one. In order to facilitate taking a pump apart and cleaning it, the working parts should be readily accessible.

Single-acting pumps.—The simplest single-acting pumps have but one set of ports or valves. The cylinder is emptied and at the same time filled by the upward, or backward, stroke of the plunger; it remains filled during the return stroke, the plunger passing through the liquid, as in the common pitcher pump, and is again emptied and filled at the next upward, or backward stroke. The typical double-acting pump, on the other hand, is provided with at least two sets of ports or valves. The cylinder is filled from one end at one stroke and emptied at the return stroke of the plunger, filling at the same time from the other end.

Some single-acting pumps have the cylinder submerged in the liquid while others have the cylinder placed on the outside of the tank or barrel. The latter are too well known to need description. Among pumps having the cylinder on the outside of the barrel are several made by W. and B. Douglas (one of them is shown in Fig. 19), the Deming Co's. Gem, Simplex (Fig. 20) and Peerless, and the Field Force Pump Co's. Empire Queen, Empire King (Fig. 21) and Empire Junior. Pumps of the submerged cylinder class, that is, pumps which are near the bottom of the barrel or tank and submerged in the liquid, have certain peculiar merits. From their location they can use simpler valves, they never need priming as the valves are always flooded and there are no projecting parts to catch on limbs. Most of the pumps of this class are made with short cylinders, but a few have long cylinders. Among such are the Defender (Fig. 22) and the Little Giant of J. F. Gaylord, and the Myers brass barrel pump. To the class of inside pumps with short cylinders belong Morrill and Morley's Eclipse (Fig. 23), the Myers Improved brass barrel pumps (Fig. 24). Goulds' Pomona (Fig.

25), Savelot and Fruitall, and the Deming Century. A variation of this form is found in the Hardie (Fig. 26) and the Spramotor (Fig. 27), in which the pump is supported in the middle of the barrel on a foot piece.

So-called double-acting pumps.—Some hand pumps are designated as double-acting, meaning in this case that a part of the contents of the cylinder is discharged through the port with the forward stroke of the lever and the rest with the return stroke. These pumps maintain a continuous and uniform discharge at the nozzles with a small air chamber or even with none at all. Goulds' Standard (Fig. 28) is an example.

True double-acting pumps.—The true double-acting pump is one in which a certain quantity of liquid is taken in and also a like quantity discharged at both the forward and the return strokes of the lever. Pumps of this type used for spraying purposes are usually horizontal pumps. They are of large capacity and are generally used with a tank outfit, though Brown's Siphonette is regularly used also with a barrel outfit. They of course require more expenditure of power than do single acting pumps of the same cylinder dimensions. Goulds' Sentinel Jr., Douglas' horizontal double-acting, the Friend, Brown's Siphonette (Fig. 29) and Deming's Planet (Fig. 31) are examples of this class.

Two-cylinder pumps.—A two-cylinder pump is described by its name. It consists of two independent cylinders operated by a common lever. These pumps have great capacity and are used on tank outfits. To this class belong Goulds' Monarch (Fig. 32), Brown's Hydraplex and the Friend Horizontal (Fig. 33).

Rotary or "clock" pumps.—The rotary or clock pump is theoretically one of the best adapted to spraying purposes, but practically quite otherwise. These pumps have good capacity and are easier of operation than others here mentioned, but from the nature of their operation, which is that of two metal surfaces in contact with each other, they are short-lived. These working parts are made of brass and this soft metal is very soon worn. A pump of this type is shown in Fig. 30.

Hydraulic pumps.—A hydraulic spray pump consists of a pump and a larger air chamber into which the spray liquid is pumped under pressure. The power that immediately expels the liquid is derived from the cushion of compressed air which has been formed. With pressure once up a spray may be thrown for several minutes without operating the pump. The pump is attached to an air chamber having a capacity of from 10 to 12 gallons. A pipe extends downward from the top of the air chamber to a point near the bottom, the upper end being connected with the discharge pipe. The liquid is pumped into the air chamber through check valves, and is forced by the compressed air through the discharge pipe.

This type of pumps presents certain peculiar and undesirable features. Sediment is likely to settle on the valves unless there is provision for agitating the liquid other than the stream as it enters the chamber. Special care must be taken in packing these pumps and all joints must be extra strong on account of the great pressure which must be withstood. The air chamber should be provided with a pressure gauge. To this class belong the Field Force Pump Co's. Niagara and the Myers Hydraulic Pump (Fig. 34).

Special features.—The air chamber of a spray pump may be painted with asphaultum to prevent bordeaux mixture attacking the iron and thus causing flakes to fall into the spray mixture. A perfect coating should be applied as corrosive action may begin through the smallest break in the covering. Pumps with porcelain-lined cylinders have been made. They have proved unsatisfactory, however, because it is almost impracticable to get all lumps out of the lime used in making the porcelain and these soon wear the plunger. We have had no opportunity of testing these pumps.

NOZZLES.

The subject of spray nozzles and their efficiency was investigated by Professor N. O. Booth while at the Missouri Experiment Station and the results are reported in Bulletin 50 of that Station. The matter given under this subhead is abstracted in large part from that bulletin.

Classification of spray nozzles.—Professor Booth classifies nozzles according to their manner of forming the spray.

"CLASS I.—The first class both in simplicity and date of manufacture is the solid, more or less round, stream. Here the water emerges in the form of a solid stream and the spray is formed by the action of the air upon this stream. No nozzles are now on the market in which this is the sole method of forming the spray, but it is one adjustment of several of the variable stream nozzles. A high pressure is necessary in using such nozzles in order to secure the velocity required to break the stream into a spray. These are all long distance nozzles designed for the tops of trees, etc. The fault with sprays formed in this manner is that they are not homogeneous throughout. The air acts upon the outside of the stream first and when this is well broken up the center is still composed of very large drops if not wholly inact. The following nozzles utilize this method of forming a spray: Excelsior, Niagara, Seneca, Masson, Calla, Bordeaux and Lewis' Patent.

"CLASS II.—The second class embraces those nozzles in which the spray is more or less broken directly by the action of the margin of the outlet. In all sprays the disintegrating action of the air is a factor but in this and the succeeding classes, owing to the fact that the air has equal access to all parts of the stream its action is more uniform than in the first class. Nozzles belonging to this class are: Niagara, Pilter Bourdil, Seneca, Masson, and Bordeaux.

"CLASS III.—The third class includes those nozzles in which the stream, having passed the outlet proper, is broken into a spray by striking against projecting parts of the nozzle. To this class belongs Lewis' Patent. * * *

"CLASS IV.—Nozzles in which a rotary motion is given to the liquid in a chamber adjacent to the outlet and in consequence of this motion the stream emerges in the form of a conical spray. In some cases this rotary motion is given by the direction of the channel leading to the chamber, and in others it is produced after introduction into the chamber by spirals in a spindle inside the chamber. To this class belong all the Vermorels, Australian and Cyclone.

"CLASS V.—Nozzles in which the liquid escapes in the form of two converging streams the force of which, acting upon each other at the point of contact, breaks the liquid into a spray. This spray is fan-shaped and lies in a plane at right angles to the plane of the two converging streams. To this class belong Excelsior, Calla and McGowen.

"The classes II and III blend together so that some nozzles may be placed in one of the other according to the judgment of the person making the classification. Most of the variable spray nozzles fall into different classes as the adjustment is changed."

Among recent introductions not mentioned by Professor Booth are:

Brown's Universal Vermorel, Classes I and IV.

Field Force Pump Co's. Dewey, Class IV.

Spramotor, Class IV.

Goulds' Mistry and Large Mistry, Class IV.

Illustrations of the different classes are shown in Figs. 4 to 13, as follows:

Class I. Deming's Bordeaux, Fig. 4; Calla, Fig. 5, Lewis, Patent, Fig. 6.

Class II. Deming's Bordeaux, Fig. 4.

Class III. Lewis' Patent, Fig. 6.

Class IV. Vermorels, Dewey, Cyclones, Figs. 7 to 13.

Class V. Calla, Fig. 5.

Clogging and dribbling.—Many nozzles, including all Vermorels, have devices for clearing the opening when clogged. Professor Booth finds that experimental tests and field experience unite in showing that none of the common spraying nozzles will clog when used with any of the common spraying mixtures "if these be carefully prepared and the spraying vessels and pump be kept clean by washing out after being used. Lint and thread may clog any nozzle and every precaution should be taken to keep these out of the liquid. Sometimes, owing to poorly burned lime or some other unpreventable cause, a nozzle will clog badly. Under these circumstances it is a great convenience if it can be readily cleaned."

EXPLANATION OF PLATES XXI TO XXVIII.

PLATE XXI.

Bordeaux mixture made by mixing (A) concentrated solutions, (B) dilute solutions:

FIG. 1.—*Just made.*
FIG. 2.—*After standing twenty minutes.*
FIG. 3.—*After standing one hour.*

PLATE XXII.

FIG. 4.—*Deming Co.'s Bordeaux.*
FIG. 5.—*The Goulds Mfg. Co.'s Calla.*
FIG. 6.—*J. F. Gaylord's Lewis' Patent.*
FIG. 7.—*Single Vermorel (Morrill & Morley).*
FIG. 8.—*Two-cluster Vermorel (Morrill & Morley).*
FIG. 9.—*Three-cluster Vermorel (Morrill & Morley).*
FIG. 10.—*Four-cluster Vermorel (Morrill & Morley).*
FIG. 11.—*Field Force Pump Co.'s Dewey.*
FIG. 12.—*Wm. Stahl's Cyclone.*
FIG. 13.—*F. E. Myers & Bro.'s Hop Nozzle.*
FIG. 14.—*Pierce-Loop Spray Co.'s "Separator."*

PLATE XXIII.

FIG. 15.—*Independent Whirling-paddle Agitator.*
FIG. 16.—*Hardie Spray Pump Mfg. Co.'s Knapsack Outfit.*
FIG. 17.—*Hardie Spray Pump Mfg. Co.'s Wheelbarrow Outfit.*
FIG. 18.—*Field Force Pump Co.'s Truck and Barrel Sprayer.*

PLATE XXIV.

FIG. 19.—*W. & B. Douglas' Single-acting Barrel Pump Outfit, showing jet agitator.*
FIG. 20.—*The Deming Co.'s Simplex Barrel Spray Pump, showing also the Deming agitator.*
FIG. 21.—*Field Force Pump Co.'s Empire King Spray Pump Outfit, showing agitator working back and forth.*
FIG. 22.—*J. F. Gaylord's Defender Spray Pump Outfit, showing up-and-down dasher agitator.*

PLATE XXV.

FIG. 23.—*Morrill & Morley's Eclipse Spray Pump, showing agitator combining up-and-down and sidewise actions.*

FIG. 24.—*F. E. Myers & Bro.'s Improved Brass Barrel Spray Pump, showing jet agitator.*

FIG. 25.—*The Goulds Mfg. Co.'s Pomona Spray Pump Outfit, showing dasher agitator working sidewise.*

FIG. 26.—*The Hardie Spray Pump Mfg. Co.'s Barrel Outfit, showing up-and down dasher agitator.*

PLATE XXVI.

FIG. 27.—*Spramotor Pump, showing one type of dasher agitator.*

FIG. 28.—*The Goulds Mfg. Co.'s Standard.*

FIG. 29.—*E. C. Brown & Co.'s Siphonette.*

FIG. 30.—*Wm. Stahl's Excelsior Clock Pump.*

PLATE XXVII.

FIG. 31.—*The Deming Co.'s Planet Double-acting Spray Pump.*

FIG. 32.—*The Goulds Mfg. Co.'s Monarch Two-cylinder Spray Pump.*

FIG. 33.—*The Friend Horizontal Spray Pump.*

FIG. 34.—*F. E. Myers & Bro.'s Hydraulic Spray Pump.*

PLATE XXVIII.

FIG. 35.—*The Deming Co.'s Planet Horse Power Sprayer.*

FIG. 36.—*E. C. Brown & Co.'s Five-row Two-horse Potato Sprayer.*

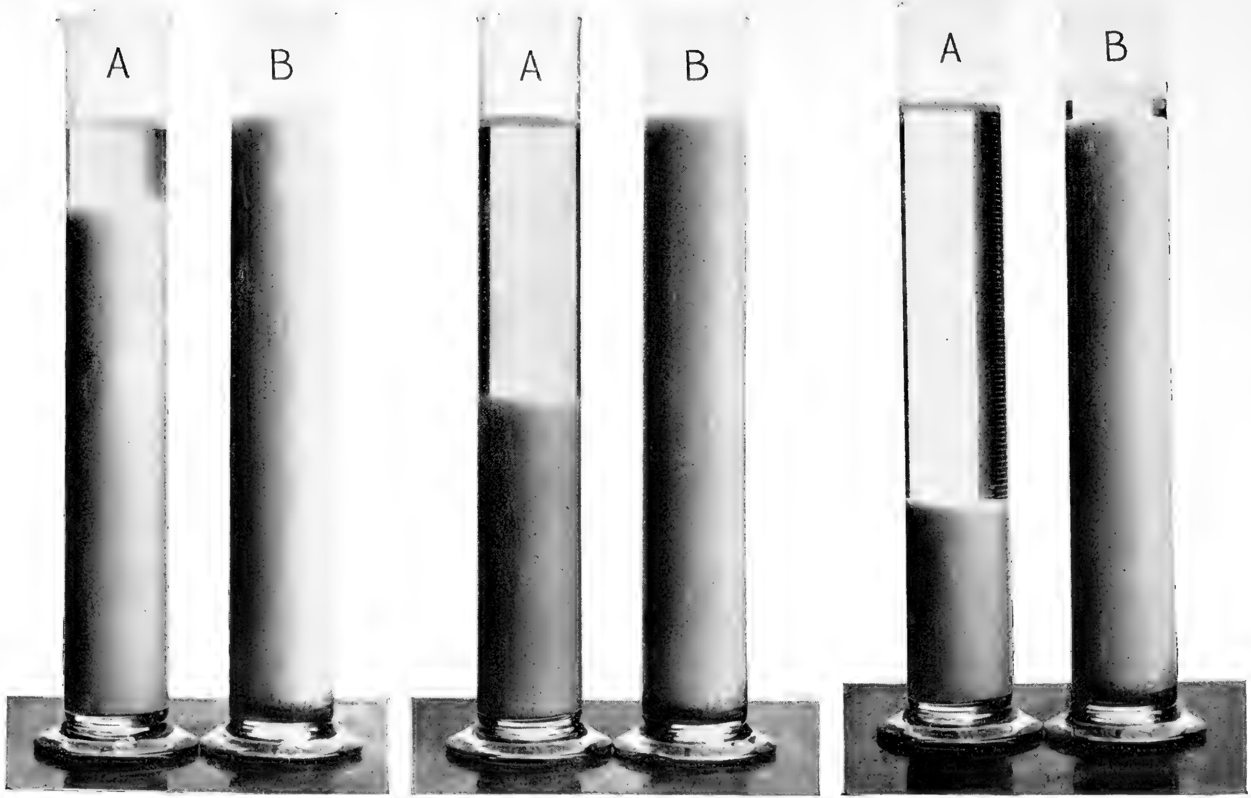


Plate XXI.—Bordeaux Mixture Differently Made.

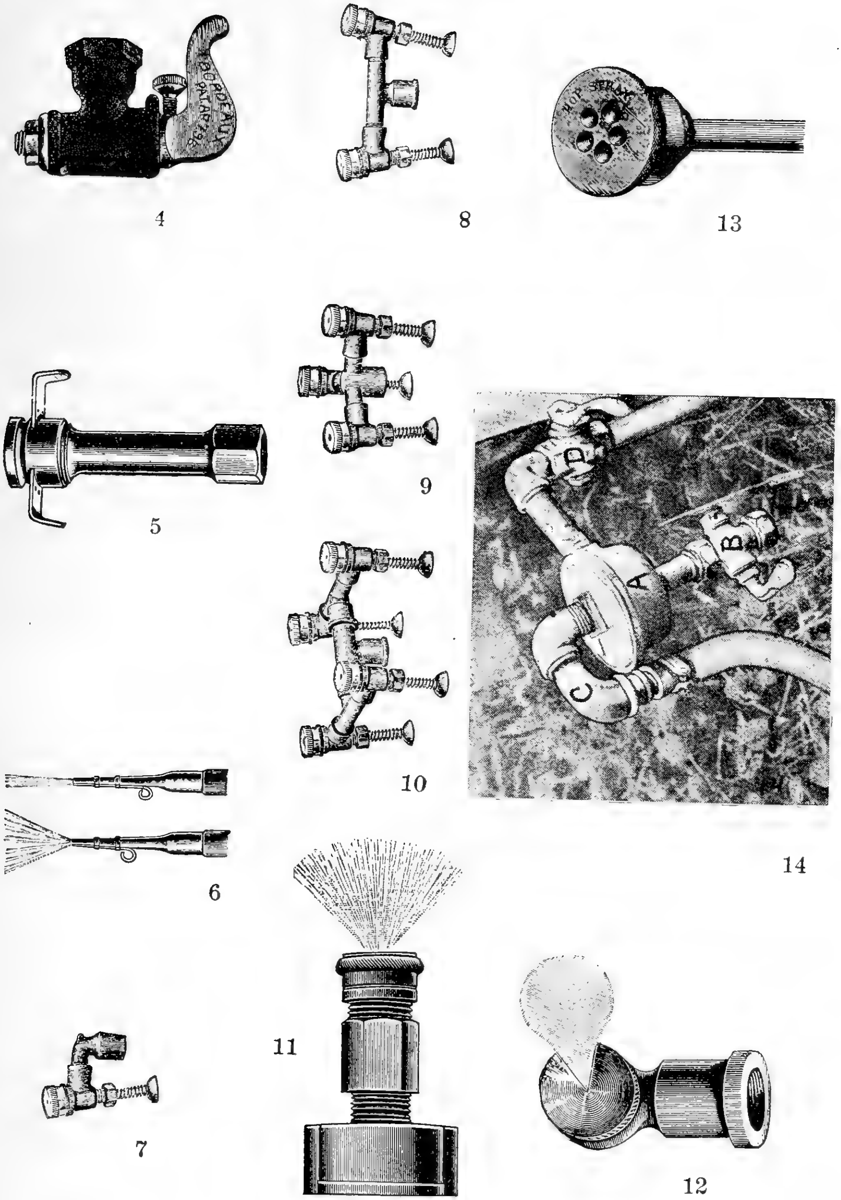
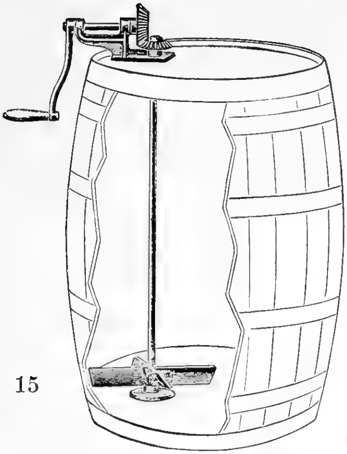


PLATE XXII.—NOZZLES; LOOP SEPARATOR.



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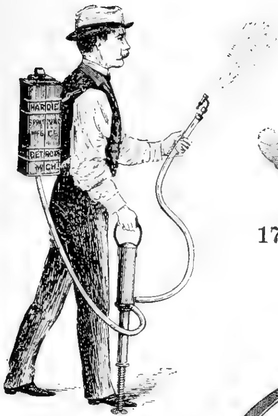

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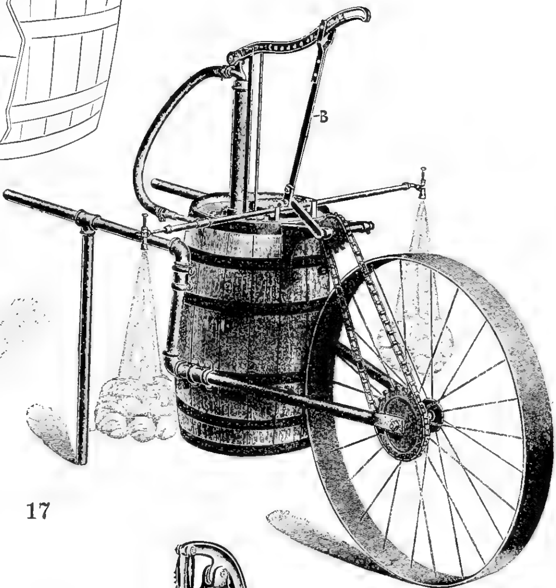

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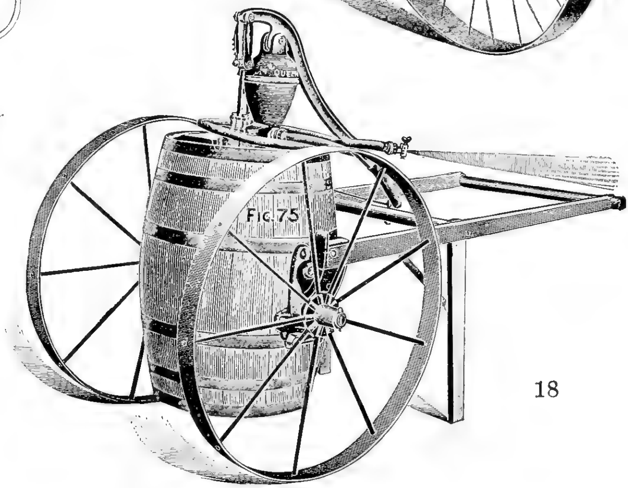

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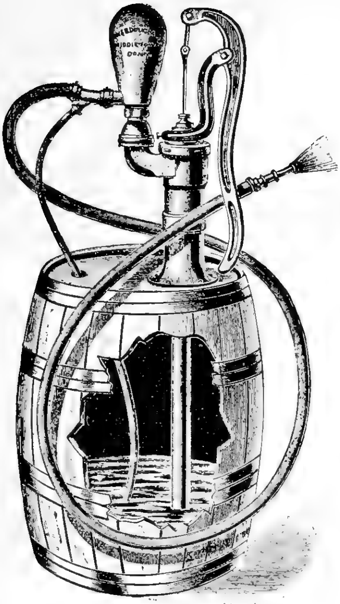
Plate XXIII.—Independent Agitator, Knapsack, Wheelbarrow and Cart Outfits.



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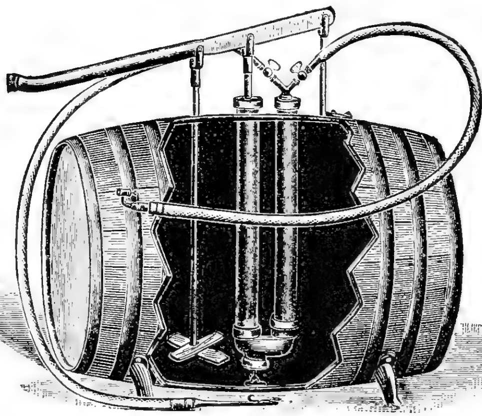

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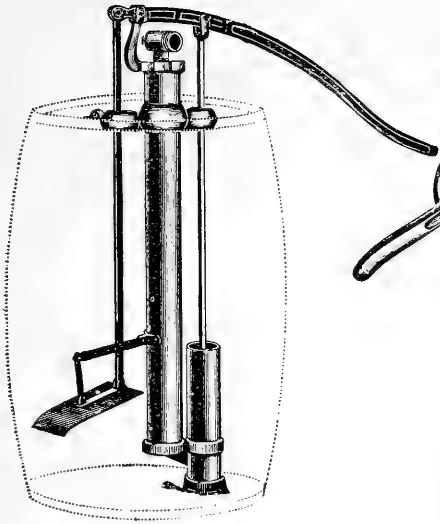
Plate XXIV.—Barrel Outfits and Agitators.



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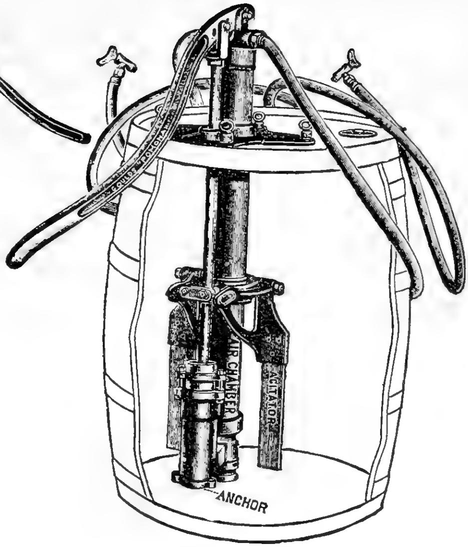

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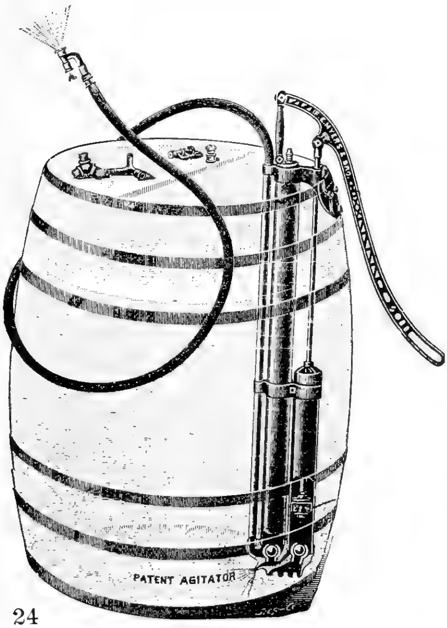

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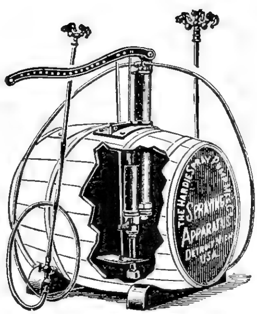

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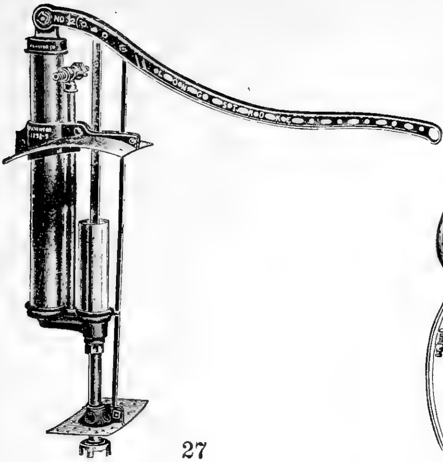
Plate XXV.—Barrel Outfits and Agitators.



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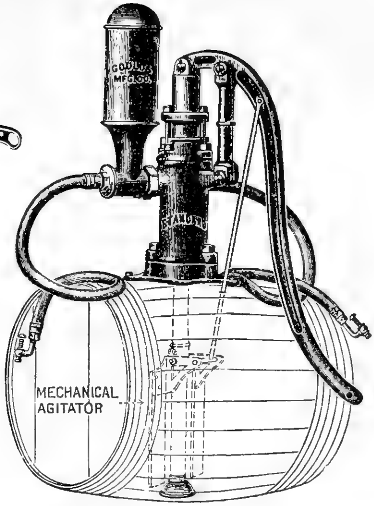

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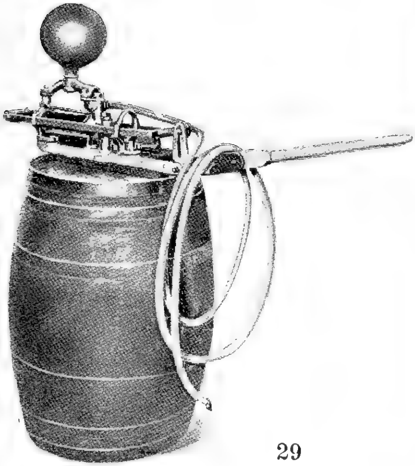

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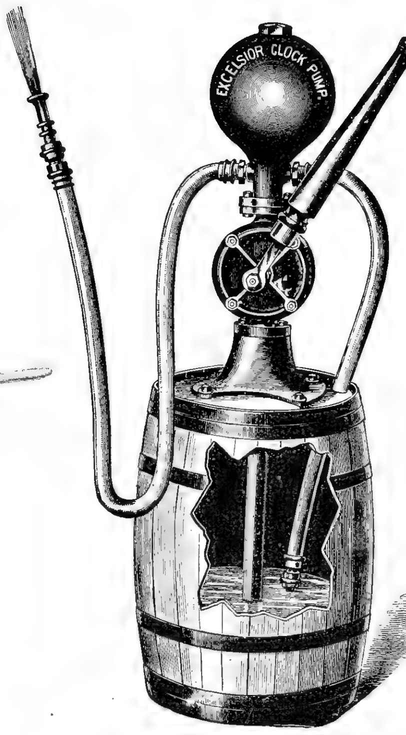

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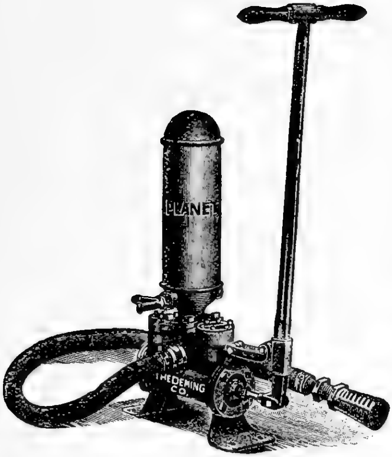
PLATE XXVI.—BARREL OUTFITS.



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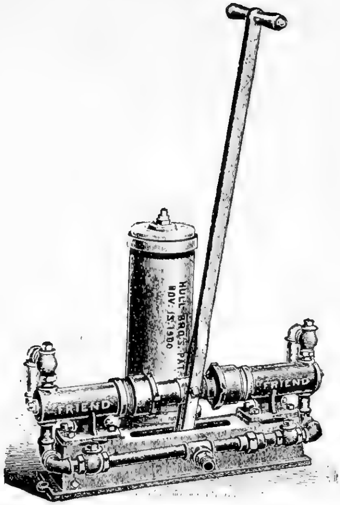

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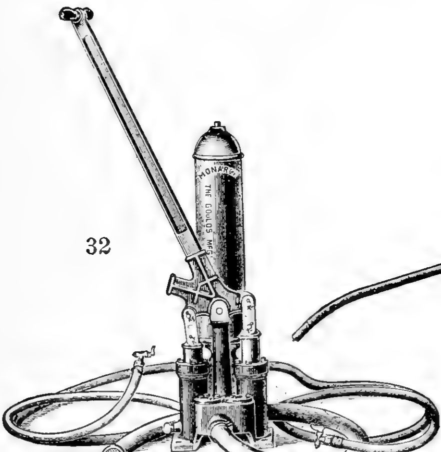

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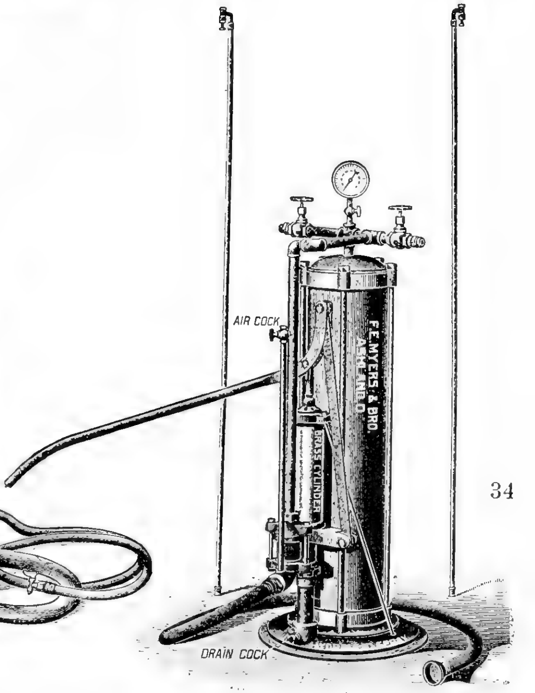

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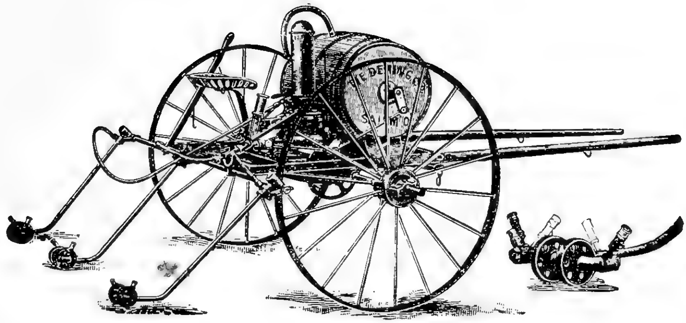
PLATE XXVII.—PUMPS.



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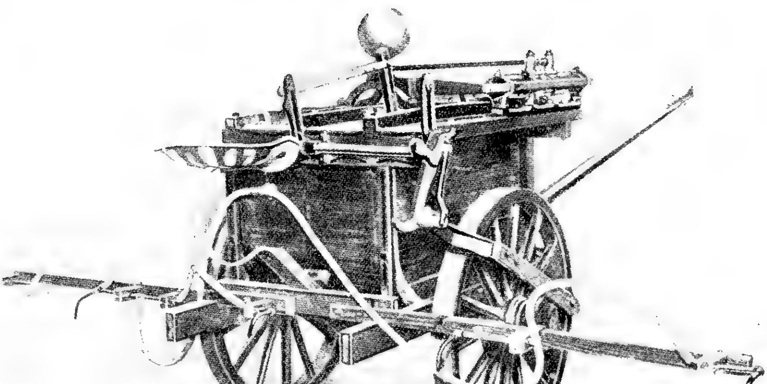

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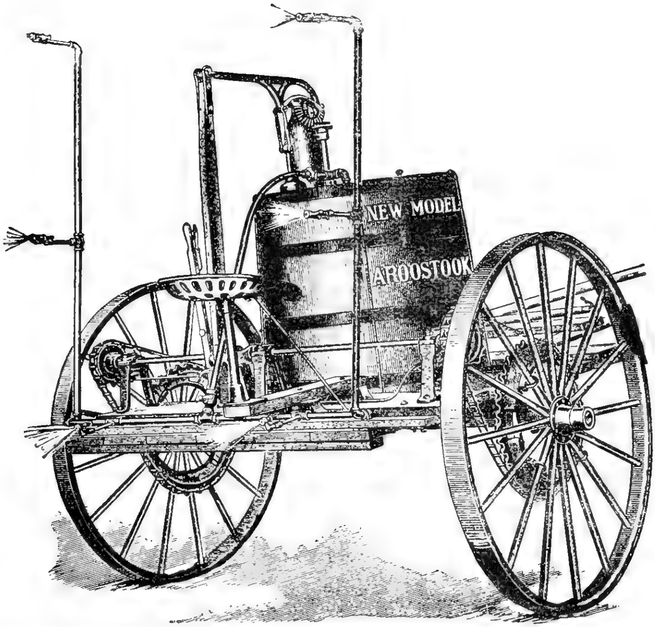
Plate XXVIII.—Row Sprayers.



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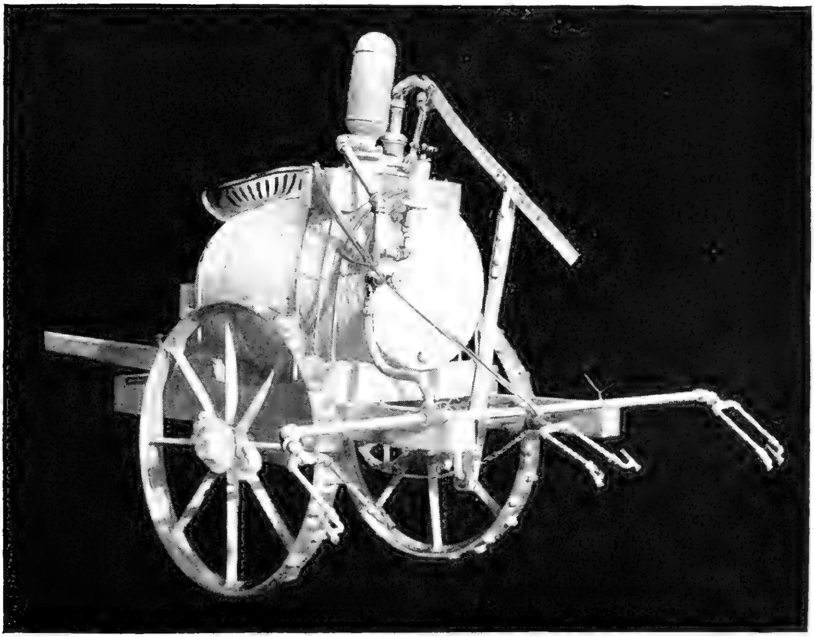

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PLATE XXIX.—FIELD-CROP SPRAYERS.

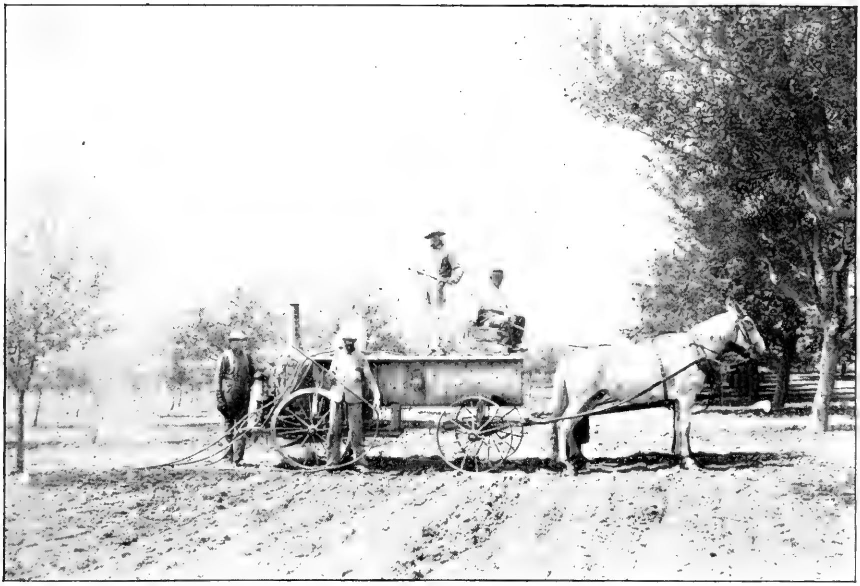

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Plate XXX.—Steam-Power Sprayers.

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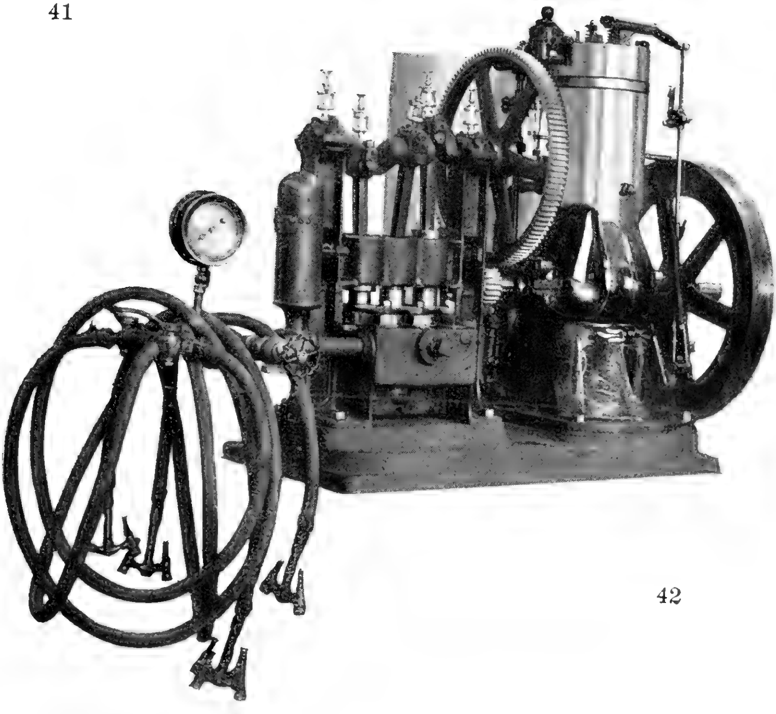

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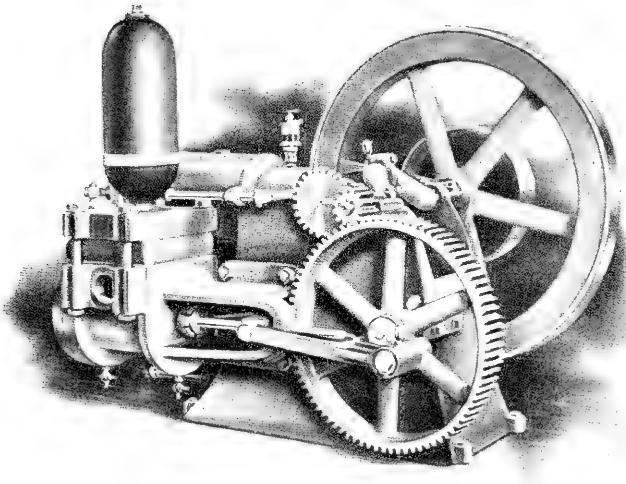
PLATE XXXI.—STEAM-POWER OUTFIT AND VERTICAL GASOLINE ENGINE.



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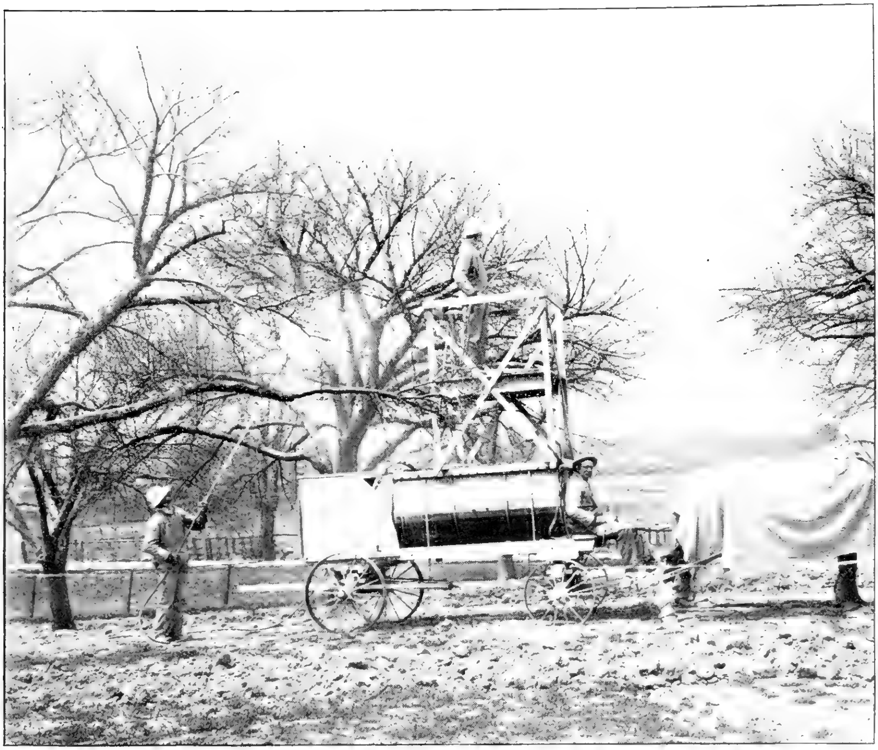

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PLATE XXXII.—HORIZONTAL GASOLINE ENGINE AND GASOLINE-POWER OUTFIT.

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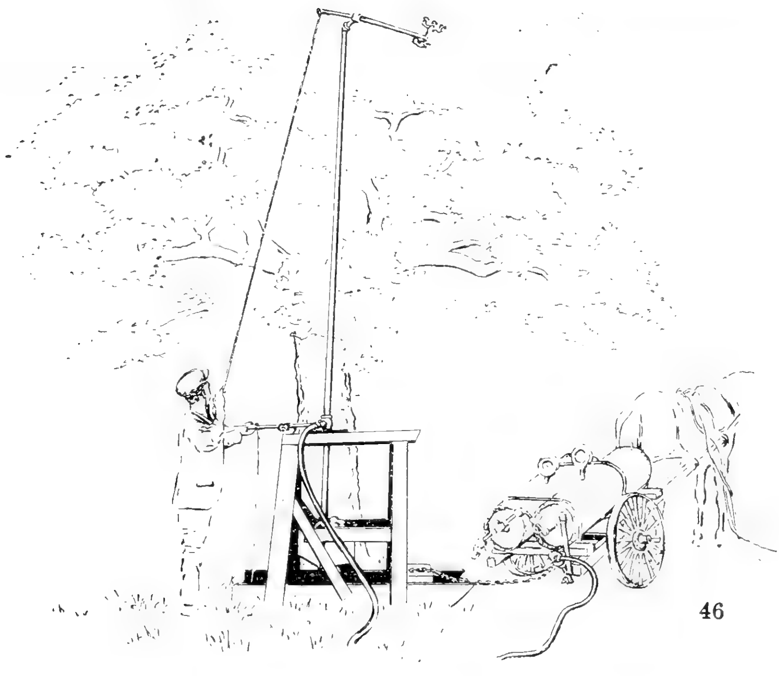

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PLATE XXXIII.—COMPRESSED-AIR OUTFITS AND STAND-PIPES.

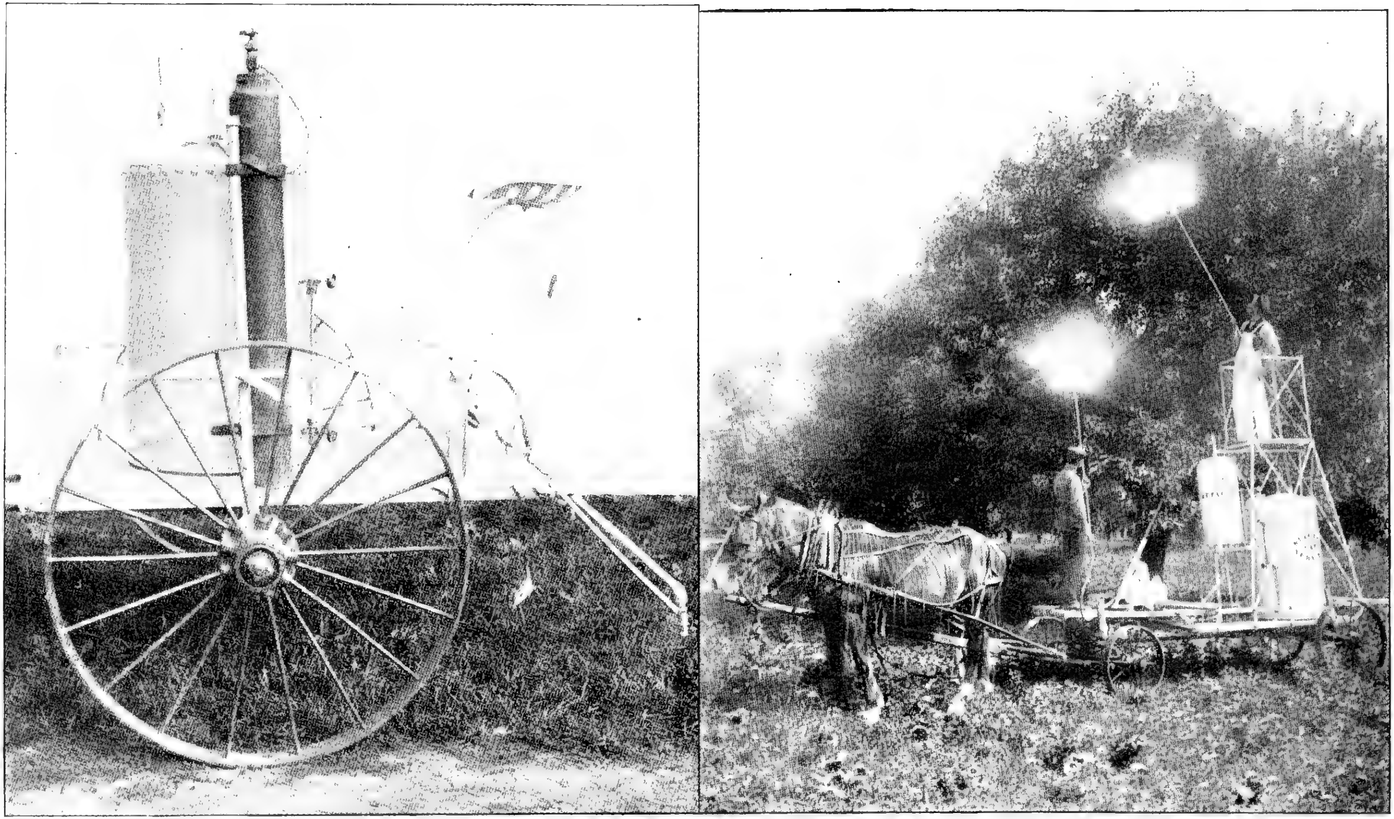
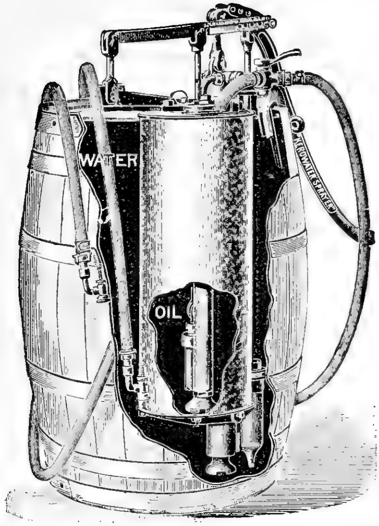


Plate XXXIV.—Gas-Power Sprayers.



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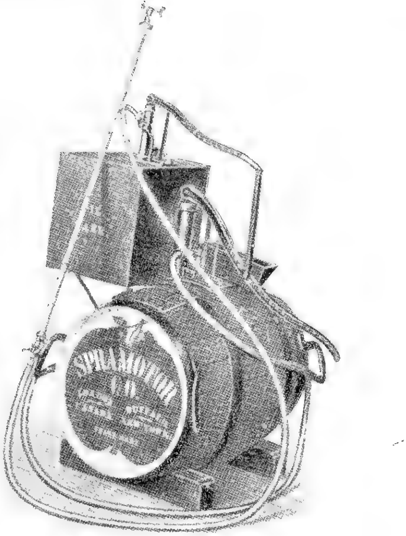

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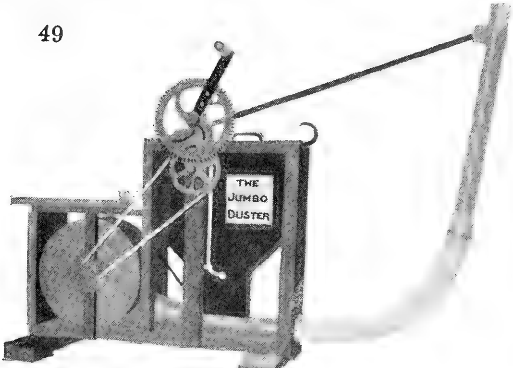

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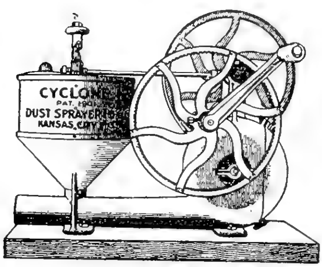

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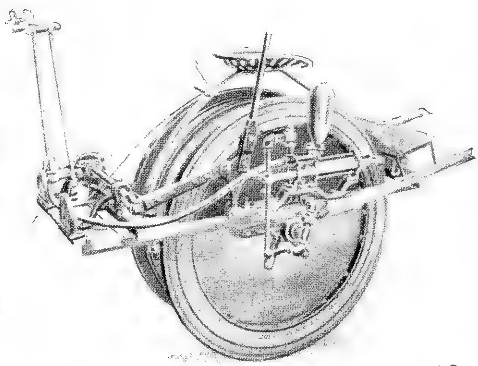

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PLATE XXXV.—KEROSENE ATTACHMENTS, DUST SPRAYERS AND NURSERY RIG.

EXPLANATION OF PLATES XXIX TO XXXV.

PLATE XXIX.

FIG. 37.—*The Field Force Pump Co.'s Field-crop Sprayer "Aroostook."*

FIG. 38.—*J. S. Armstrong's Home-made Potato Sprayer.*

PLATE XXX.

FIG. 39.—*Albert Wood & Son's Steam Power Sprayer; showing also bed pieces, bolsters; hose tied to bamboo fish poles; also use of high hind wheels on wagon; half-round horizontal tank.*

FIG. 40.—*J. B. Collamer's Steam Power Outfit; showing also bamboo extension rods; also half-round horizontal tank with top of same used for platform; also engine hung from rear axle; also truck built without bed-pieces.*

PLATE XXXI.

FIG. 41.—*T. B. Wilson's Steam Power Outfit; showing also use of top of tank as spray platform.*

FIG. 42.—*The Goulds Mfg. Co.'s Gasoline Power Spraying Outfit.*

PLATE XXXII.

FIG. 43.—*Lunt, Moss & Co.'s Gasoline Engine and Power Spray Pump.*

FIG. 44.—*The Geneva Experiment Station's Gasoline Power Spray Outfit; showing engine and pump enclosed by canvas, half-round tank and removable tower.*

PLATE XXXIII.

FIG. 45.—*The Pierce-Loop Sprayer Co.'s Compressed-air Spraying Outfit. Showing also the Owen standard.*

FIG. 46.—*The Loop Standpipe, used with Pierce-Loop Compressed-air Sprayer.*

PLATE XXXIV.

FIG. 47.—*The Niagara Spraying Mfg. Co.'s Two-horse Outfit; showing the tall, narrow tube containing liquified carbonic acid gas.*

FIG. 48.—*The Niagara Spraying Mfg. Co.'s Orchard Outfit; showing steel tower; also wagon with platform raised in front.*

PLATE XXXV.

FIG. 49.—*Goulds Mfg. Co.'s "Kerowater" Barrel Outfit for spraying mechanical mixtures of kerosene and water.*

FIG. 50.—*Spramotor Co.'s Barrel Outfit for spraying mechanical mixtures of kerosene and water.*

FIG. 51.—*Leggett & Bro.'s Jumbo Duster.*

FIG. 52.—*Dust Sprayer Mfg. Co.'s Cyclone Dust Sprayer.*

FIG. 53.—*E. C. Brown & Co.'s Nursery Rig.*

"A great many nozzles, owing either to faulty construction or to wear, dribble. In new nozzles this is seldom serious but in old and worn nozzles it frequently gets to be a regular stream. This is not only a waste of liquid but also a great annoyance to the operator as all or part of this waste usually runs down the pole or extension rod on to his hands and arms. It is particularly disagreeable if the mixture be caustic. Nozzles will dribble worse with thicker liquids than with those of thinner nature. * * * Many otherwise good nozzles are deficient in this respect."

Tests showed that none of the Vermorels dribble, but most of them have a stuffing box at the end of the spindle which may leak if not kept packed. Fan-shaped sprays in a number of nozzles dribbled.

The best nozzle.—The experiment Station often receives inquiries as to which is the best kind of nozzle to use in spraying. This question is discussed under the heading of "The Most Desirable Spray," p. 343.

Vermorel nozzles.—In the opinion of the writers the best nozzles for use in fruit plantations are those of the Vermorel type. Manufacturers have devised several modifications of the Vermorel nozzle. One recently introduced makes it possible to change from a solid stream to a fine spray. The modifications adopted in the Spramotor, Goulds' Mistry and Goulds' Large Mistry give a very broad cone-shaped spray and the spray is very fine. The Goulds Mistry throws a finer spray with a low pressure than does the common Vermorel. It is supplied with a cleanout by which solid substances may be removed from the piping or from the stem of the nozzle. Goulds' Large Mistry is capable of covering a considerably larger area than do the common Vermorels. It is made with a swivel which permits of throwing the spray in any direction. When two of these nozzles are mounted on a Y the most varied directions may be given to the spray by changing the adjustment of the individual nozzles.

Cyclone nozzles.—The cyclone nozzle is the prototype of the Vermorel. It discharges the spray at right angles to the axis of the pipe which leads to the nozzle. Stahl's cyclone is shown in Fig. 12 and Myers' Hop Nozzle, a cluster cyclone, in Fig. 13. By some these nozzles with side discharge are considered specially desirable for spraying low plants and the under sides of foliage, but as a matter of fact they are not superior to the Vermorel.

Cluster nozzles.—A group of nozzles supplied by one lead of hose is called a "cluster." By means of suitable attachments these clusters may include two or more nozzles. Other things being equal this increase in the number of nozzles attached to one lead of hose increases the area which may be covered by one workman in a given period of time. Some of the best and most experienced managers of spraying outfits hold the opinion that with good apparatus and good pressure it is not economical to include more than two Vermorel nozzles in a cluster. A double Vermorel is shown in Fig. 8 and triple and quadruple forms in Figs. 9 and 10. In some clusters Vermorel nozzles are used to give a very fine spray carrying but a short distance while adjustable nozzles at the same time throw a coarser and farther reaching spray.

Nozzle accessories.—Various kinds of nozzle attachments are offered, as Y's, strainers or separators, shut-off discharge connections and devices by which the spray may be driven at any angle to reach any surface.

The Loop separator.—This is a strainer which is attached to the discharge pipe of the tank for the purpose of separating from the liquid any particles which might clog the nozzle. See Fig 14. It consists of a brass cup separated into two chambers by a disc of wire cloth. The liquid enters the lower chamber, passes through the wire cloth to the upper chamber from which it is discharged into the hose leading to the nozzle. In the bottom of the cup is an orifice which may be opened at will for cleaning the chamber of sediment. This

device has but recently been put upon the market. It appears to be a good one. We have not yet seen it tested.

AGITATORS.

Agitators are of either (1) the mechanical or (2) the jet type. The former have the greater variety of forms, the wider use and in most cases the greater efficiency.

Mechanical agitators are of the dasher type or of the whirling paddle type. In barrel outfits the dasher type is most frequently used but with large tanks the whirling paddle type prevails.

Dasher agitators.—The dasher forms work up and down or sideways or both ways. Those which work up and down are used in the larger number of barrel outfits. They are attached to the pump handle and operate in close proximity to the end of the suction pipe. An objection to them is that they do not keep the liquid equally well mixed throughout the barrel. Of this type are Goulds' Standard, Spramotor (Fig. 27), Hardie (Fig. 26), Defender (Fig. 22) and Myers' barrel agitator.

Similar in principle and attachment are some of the dasher forms which work sideways. These are Goulds' Fruitall, Pomona (Fig. 25) and Savelot, the Field Force Pump Co.'s barrel agitator (Fig. 21), and the agitators used in some of the horizontal half-round tanks.

Up and down and sideways actions are combined in the Eclipse (Fig. 23) and Deming agitators. The Eclipse agitator is a brass spoon-like paddle. The Deming (Fig. 20) is simply three separate paddles actuated by a common rod, one paddle working up and down and the other two sideways. Among the dasher agitators this last class is the most efficient.

Whirling paddle agitators.—One form of the whirling paddle type is illustrated by the independent revolving agitator (Fig. 15), which was devised by Mr. C. K. Scoon of Geneva, and first brought to the

attention of the public by this Station (see Bulletin 121). As the paddles revolve the liquid is carried both around and upward in the barrel, giving thorough agitation. With fixed tanks this device may be fitted with chain and sprocket so as to be driven by the wagon wheel. This has been done by Maxwell Bros., of Geneva, who have a power outfit with unright cylindrical tank, the agitator of which consists of two banks of whirling tilted paddles, one at the bottom of the tank and one at about the middle. The mechanism is geared to one hind wheel.

The agitator in the steam power outfit made by the Rochester Machine Tool Works consists of a bronze shaft, connected with the engine by a flexible coupling. On the shaft are two small blades similar to propeller-wheel blades, which revolve near the bottom of the cask. The speed can be varied at the pleasure of the operator. Agitators built after the screw-propeller model which are used with some large tanks are geared to a wagon wheel by sprocket and chain attachment.

In the outfit of A. Wood & Son of Carlton Station the agitator is built like the fan of a fanning mill on a horizontal shaft. It is driven by means of chain and sprockets attached to one of the wagon wheels. This device is frequently found in use with large tanks. It gives good satisfaction.

Morrill and Morley make a horizontal, half-round, self-agitating tank. It is divided into three compartments by bulkheads extending to within 6 inches of the bottom, with a view to forcing the mixture along the bottom, and upwards against the bulkheads and ends of the tank.

The whirling paddle type of agitator thus far has generally proved the most efficient in use. These agitators continually throw the liquid upward and outward from the whole bottom of the tank, giving a thorough agitation. Most agitators of this type are independent of the pump and this is an advantage. The operations of pumping

and of agitating require very different kinds of strokes to get the best results. Pumping requires a slow, steady stroke, while a quick, sharp motion is best for agitation. The fact of being independent also permits of agitation before pumping begins, a time when the spray mixture is especially liable to be lacking in uniformity. This is not practicable in most outfits in which agitators and pump are actuated by a common lever. But in a few cases the plunger of the pump can be readily detached from the lever by simply withdrawing a pin, and the mixture can receive a preliminary agitation. In the case of jet agitators of course the preliminary agitation can be given by pumping back into the tank.

Jet agitators.—Jet agitators operate by returning a small stream of liquid under pressure from the pump to the bottom of the tank. Two are shown in Figs. 19 and 24. Jet agitators have been almost wholly discarded in practical work with hand pumps because it is impossible in pumping by hand to keep up pressure enough to support the best kind of a spray even when none of it is used for returning a stream into the tank. While jet agitators in general as used in hand outfits, rank below the mechanical agitators in efficiency, as used in power outfits with excess of power they may be made very efficient. With them it is possible to agitate the liquid before spraying begins, which is a decided advantage. Moreover, when made of brass they do not offer a surface on which sediment can collect, to dry when the tank is not in use and to scale off later with resulting liability to clog the nozzles.

EXTENSION RODS.

Extension rods are used in connection with discharge hose for such purposes as reaching the higher branches of trees. By their use the spray can be put where wanted, whether into the interior of the tree or on the outermost branches.

Extension rods are of two kinds, pipes supported by a rod of wood and pipes with no support. The former usually consist of a length of

one-fourth or three-eighths inch brass or iron pipe fitted inside a bamboo rod. See Fig. 40. The length is commonly 8 feet but varies from 6 to 12 feet. Frequently three-eighths inch hose is used instead of an extension rod. In such cases the hose is usually tied to common stiff bamboo fish poles (as shown in Fig. 39) for reaching distant points. Very good extension rods may be made by fitting a brass pipe into a groove in a suitable piece of light pine.

Extension pipes are similar to bamboo extension rods with the omission of the bamboo itself. They are not so stiff or durable but are cheaper. Their smallness is against them, because they cramp the hands when used for a considerable length of time. They are made in iron or brass, generally in 6 or 8 foot lengths.

Drip guards are devices for protecting the hands of the operator from the drip from the nozzles. They may be attached at the middle of the rod or just under the nozzle or just above the hand of the operator. A home-made shield may be made of any stiff leather.

HOSE.

Spraying outfits should be supplied with hose capable of withstanding a pressure of at least 125 pounds to the square inch. Three ply and four ply are most used but some prefer five ply or six ply. One-half inch hose is most commonly used but some prefer a three-eighths inch hose. There is much complaint of hose wearing out rapidly under the strain of power pumps. To meet this difficulty some use the less expensive three ply hose and buy a new supply each season. Others buy stronger, more expensive hose. We are in doubt as to which is the more economical course in the long run. As to the length of hose required in orchard spraying, from 20 to 50 feet is used if the operator stands on the ground and 8 to 12 feet if he stands on a tower.

TOWERS.

If the trees are so high that the tops cannot be sprayed from the ground or the wagon, it is necessary to provide a more elevated posi-

tion from which the highest branches may be reached. In some cases the workmen stand or sit on the top of the spray tank. See Figs. 40 and 41. In others an elevated platform is built, which is provided with a railing to prevent the workmen from being thrown off. See Fig. 44. Towers are simple in construction and require no further description.

TRUCKS.

High wheels behind, 60 to 70 inches in diameter, give a decided advantage in driving over soft ground. See Fig. 39. It is almost necessary however to have the front wheels low enough to cut under the platform for convenience in turning short. With heavy outfits it is best to use wide tires; on soft ground they are almost a necessity. Those 5 or 6 inches in width are most often used, but some use 7-inch tires.

Bolster springs are a desirable addition to heavy outfits. They make the load easier on both horses and wagon. See Fig. 39.

STRAINERS.

The nozzles are less liable to become clogged when all mixtures are strained into the tank. For this purpose brass wire cloth of about 20 meshes to the inch is best. Burlap is unsatisfactory because the lint from it clogs the nozzles. A strainer should also be attached to the end of the suction pipe. It is well to have this in the shape of a hood two or three times the diameter of the pipe.

The Loop separator.—This is an attachment for straining the liquid as it enters the hose. It is described on p. 355.

TANKS.

The best tanks are constructed of cypress, pine or cedar, the first named being the most durable. Their durability may be increased by applying a coat of paint on the inside. This application has the further advantage of preventing the wood from becoming water

soaked and adding to the dead weight of the outfit. The capacity varies from 50 to 250 gallons, the latter being as much as a pair of horses can ordinarily draw. They are generally locally made, as the cost of shipping them any great distance is considerable. But there are numerous exceptions to this statement.

Spraying tanks are commonly distinguished as horizontal and upright cylindrical. The horizontal tanks are subdivided into those with flat and with half-round bottoms (see Figs. 39, 40, 44), the former being only occasionally met with. The bed pieces in the horizontal half-round form consist commonly of two heavy pieces of hardwood timber resting on the edges of the wagon bolsters on each side. See Fig. 39. Some outfits do not use bed pieces but have simply semi-circular false bolsters for the tank to sit in, as in Fig. 40. This gives an advantage in turning around, since the wheel can be cramped closer to the tank, but with steam outfits there is an attendant disadvantage, in that the boiler must be hung from the rear axle.

KINDS OF SPRAYING OUTFITS.

BUCKET OUTFITS.

A bucket-pump outfit consists essentially of a common force pump set in a pail or bucket, and such the simplest forms of these outfits are. In this case a pail is used with a pump held in place by the foot. A step forward was taken in the development of the apparatus when the pump was firmly attached to the pail, thus relieving the operator of the task of holding it. Then the bucket was made larger to hold five or eight gallons, or as much as a man could conveniently carry. Galvanized iron was used in its manufacture instead of wood and a lid was added to keep the liquid from slopping out. Some outfits have added a smaller vessel or can inside or outside the larger to contain oil. For this purpose an appropriate modification of the pump is necessary.

The bucket outfits are very useful in small gardens or for treating trees, shrubs, etc., about the dooryard.

KNAPSACK OUTFITS.

The knapsack outfit is well adapted for use in small plantations such as gardens and greenhouses, and in those that are inaccessible to outfits on wheels.

The pump of a knapsack sprayer is generally readily detachable from the tank for convenience in cleaning. The point at which the plunger leaves the tank should be guarded by some device for preventing the liquid which will be drawn up from running down on the back of the operator. The handle may be operated only from one side, or may be reversible. If reversible it may be changed by the mere act of turning or it may be necessary to change a link or pin.

Theoretically the knapsack sprayer does not need an agitator as the motion of the body of the operator would be expected to keep the mixture sufficiently mixed; but in practice the use of an agitator gives better results with mixtures having heavy ingredients such as bordeaux mixture and paris green. For this purpose either the jet or the swing form is used.

The Hardie knapsack apparatus, a peculiar form of the knapsack sprayer in which the pump is separate from the tank, is shown in Fig. 16.

HAND CARTS.

Hand carts are adapted for commercial work only in a small way. They are principally recommended for use in gardens and in places inaccessible to wagons. Their capacity is generally about 30 gallons, but may be 50 and in the wheelbarrow outfits is only 10 gallons. The construction of these outfits is sufficiently well understood by reference to the illustrations. A wheelbarrow outfit made by the Hardie Co. is shown in Fig. 17 and a two-wheeled truck and barrel sprayer put out by the Field Force Pump Co. in Fig. 18.

BARREL OUTFITS.

Barrel outfits differ from barrel carts only in the matter of mounting. The latter are permanently mounted on a truck while the former are carried about in a common wagon or cart or on a stoneboat.

The barrels are made to stand on end or to lie on the side, more commonly the former. In the latter case the barrel is generally mounted in a frame work to keep it from rolling. Some barrels have handles attached for convenience in moving. For one reason it is more advantageous to place the barrel on its side. This is because of better agitation. The sediment settles into a smaller space in the middle and there are no corners for it to lodge in and no sides to interfere with agitation. In spite of these facts it is more common to stand the barrel on end because this position is more convenient in using the pump.

Some manufacturers are offering barrel outfits in which the pump can be withdrawn from the barrel simply by loosening a catch, thumbscrew or similar device.

Barrel outfits are generally supplied without the barrel and are so listed. If the barrel is supplied and fitted an extra charge of $1.00 to $4.00 is made, the latter charge including the cost of a frame or support in those cases in which the barrel is laid on the side.

Barrel outfits may be grouped according to the position of the pump in relation to the barrel. Some have the pump inside and some outside, the former having the advantages of being cleaner so far as leaking is concerned, of making, in general, a more steady outfit and of avoiding the liability of limbs catching on the pump in driving under trees. On the other hand some of the pumps which are mounted on the outside of the barrel have the advantage of having the working parts always accessible. The advantages of submerged pumps have already been mentioned in discussing pumps. See p. 346.

If the pump is inside the barrel it may rest on a very short base at the bottom of the barrel or upon a longer upright base so that it

does not take up so much sediment. The various devices used with barrel outfits for agitating the liquid are described under "Agitators," p. 356, and the various pumps under "Pumps," p. 346.

The following barrel outfits are shown in Figs. 19 to 30: W. & B. Douglas' single-acting barrel pump outfit (Fig. 19), The Deming Co.'s Simplex (Fig. 20), The Field Force Pump Co.'s Empire King (Fig. 21), J. F. Gaylord's Defender (Fig. 22), Morrill and Morley's Eclipse (Fig. 23), F. E. Myers & Bro.'s Improved Barrel Spray Pump (Fig. 24), The Goulds Mfg. Co.'s Pomona (Fig. 25), The Hardie Spray Pump Mfg. Co.'s barrel outfit (Fig. 26), Spramotor (Fig. 27), The Goulds Mfg. Co.'s Standard (Fig. 28), E. C. Brown & Co.'s Shiphonette (Fig. 29) and Wm. Stahl's Excelsior outfit No. 13 (Fig. 30).

TANK OUTFITS WITH HAND PUMPS.

These differ from barrel outfits in principle only in their greater capacity and usually in the permanent mounting of the tank. They are generally provided with the more powerful double-acting or double-cylinder pumps. One advantage that they have is that they may be readily equipped with a mechanical agitator driven by sprocket gear attached to one of the wagon wheels. Those with large capacity should be supplied with trucks having wide tires.

HORSE-POWER OUTFITS.

Horse-power outfits differ in principle from the hand-power tank sprayers only in the fact that the power for working the pump is secured by gearing the pump to a sprocket wheel attached to a wheel of the rig or to the axle. There are several forms of horse-power sprayers on the market. Those which are designed for field crops or for vineyards will be discussed under separate headings, as also will those operated by compressed air.

The horse-power outfits designed for the orchard do good work with comparatively small trees, but when the tree is so large that it

cannot be thoroughly sprayed while the outfit is passing it they are not so satisfactory, because the pressure begins to go down as soon as the rig stops. Moreover, the pressure required for doing the best work on large trees cannot easily be maintained with horse-power outfits even when no stops are made.

The Deming Co. makes an outfit (see Fig. 35) especially designed for spraying field crops, as potatoes. It has a steel channel frame mounted on two large steel wheels. The pump is geared to a sprocket wheel on the axle, to which also the agitator is independently geared. There is a clutch to throw the pump out of gear. The pump may also be operated by hand for use in orchards. The crop-spraying apparatus behind consists of a horizontal piece of tubular iron from which a pipe descends backward to each of the three nozzle holders, which are mounted on little wheels with a cross bar, each carrying two nozzles. These are adjustable to throw the spray upward according to the height of the plants. Any or all of the nozzles can be cut off by stop cocks and the whole crop-spraying attachment is raised by a lever.

E. C. Brown & Co. make an outfit especially for potatoes, put together on much the same principle as the Deming outfit, but the tank used is a square box and the crop sprayer has only one jet to each row. The capacity of the tank is sixty gallons.

The same company makes a two-horse, five-row potato sprayer (Fig. 36) with a double-cylinder pump and a tank capacity of 100 gallons. This outfit has direct pitman connection and positive drive from both wheels. In both of these outfits the nozzle carrier extensions are so constructed that they fold to an upright position when going to and from the field or turning at the end of the row. A similar outfit designed especially for vineyard work has a capacity of 60 gallons, and a larger one has a capacity of 100 gallons.

The same company also makes a one-horse outfit (Fig. 53) especially suitable for narrow row plantations, such as nursery stock,

berries, etc. The tank is in the form of a drum and rolls like a roller. Its width is 19 inches and its capacity 65 gallons. The extreme width of the outfit is 32 inches, thus allowing it to be drawn between rows of high plants in the field. The round tank itself rolls, dispensing with wheels or wagon. The rolling necessarily affords agitation. The outfit is supplied with pump, nozzles, etc.

The Field Force Pump Co. manufactures three patterns of two-wheeled outfits similar in principle to the Brown outfits but having upright circular tanks. One of these is shown in Fig. 37. Both these and the Brown outfits are adapted for spraying either potatoes or grapes except in the case of the Field Force Pump outfit which is arranged for low crops alone. A larger Field Force Pump outfit has a tank with a capacity of 150 gallons and is mounted on a four-wheeled truck. The pump is connected with a chamber on the wagon of twelve gallons capacity. In driving from tree to tree the pressure in this cylinder is pumped up. The chamber also has a hand pump connected with it for use if the pressure should run out too soon.

The Wellhouse spraying machine is made by William Stahl. The tank is three and a half feet wide, four feet two inches long and fifteen inches deep. The pump is of the rotary type and is geared to a sprocket wheel on one side of the rig. The power is thrown on and off by levers.

FIELD-CROP SPRAYERS.

Field-crop sprayers are made for spraying low plants such as potatoes, cabbage, asparagus, currants, gooseberries, etc. The simplest form is the atomizer. This is used to a considerable extent in applying paris green and water to potato vines. The reservoir holds from one to two quarts. Lime should be added to the water to avoid the danger of burning the foliage by the poison. This apparatus is not suitable when there is any considerable area to cover as the work progresses slowly and it is difficult to cover all the leaf surface with the mixture.

Sometimes barrel or tank sprinklers are used. These may be mounted on a two-wheeled cart and connected at the rear with pipes having one or more nozzles for each row. No pump is used, the liquid being distributed only by force of gravity. They are comparatively inefficient since the force is not sufficient to make the most desirable kind of spray.

A modification of this type of apparatus consists of the substitution of a geared disk for the nozzles. The force of gravity causes the spray mixture to flow through a nozzle against the rapidly revolving disk where it is thrown outward by centrifugal force. There is scarcely any machinery to get out of order and clogging is almost impossible, even with unstrained materials; but much of the liquid is wasted, the plants are not prefectly or evenly sprayed and, if the wind is high and from the rear, the driver is liable to be thoroughly drenched.

Another kind of sprayer consists of the ordinary barrel and pump mounted on a two-wheeled cart. The driver does the pumping, Stationary nozzles attached behind spray two or more rows. In other cases the driver does the pumping while one or two men follow between the rows directing a nozzle with each hand. In this case it is convenient to have the lead of hose divided by a Y and have short lines of hose leading from the Y to the nozzles. The one who is spraying may carry the Y conveniently over his shoulder and hold a hose in each hand.

A better spray may be maintained with a horse-power outfit. Several large potato growers are using home-made sprayers of this kind, constructed from old potato diggers or from two-wheeled machines suitable for the purpose. In some cases it is necessary to shorten the axle to accommodate the wheels to the width of the rows. The first of these outfits was made by Mr. J. S. Armstrong of Oakfield, N. Y. His outfit (Fig. 38) consists of a barrel and pump mounted on a two-wheeled truck with an attachment behind for spraying three rows,

two nozzles to the row. It is drawn by two horses. The wheels and seat were taken from an old potato digger. To one of the wheels a sprocket wheel is attached. This is connected with an eccentric which works an upright shaft which in turn works the handle of the pump. The pump handle has several holes drilled in it, permitting different lengths of stroke. The crop sprayer attachment is of iron pipes fitted with brass nozzles. A corroded part can be cheaply replaced. The nozzles can be tilted upward when not in use, thus preventing sediment from settling into and clogging them. In general it may be said that the spray cannot be so well directed from stationary nozzles as by hand.

Nearly all of the spray-pump manufacturers are now making potato-sprayer attachments which may be connected to the ordinary spray outfit. They are also making the complete field-crop power sprayer of the type just described. In the case of wagon outfits the apparatus is generally attached at the back of the truck and has one or more nozzles for each row. They are adjustable to accommodate different widths of row. Some have special devices for throwing the liquid sideways or upward into the plants from below. They are made to spray from two to six rows at a time. By means of a folding device the crop-sprayer attachment can be turned up when going through a gate or turning at the end of a row.

VINEYARD SPRAYERS.

For vineyard use the ordinary barrel outfit is often mounted on a stoneboat or on a two-wheeled cart or wagon. It is sometimes necessary to shorten the axle of the wagon to avoid striking posts and vines. Power sprayers are also used which are very similar in principle to the field-crop power sprayers already described. The nozzles if stationary are directed so as to spray sideways, or in some cases are elevated directly over the row and spray downwards. The spray as already stated cannot be so well directed from stationary nozzles as by hand.

STEAM-POWER OUTFITS.

The information in this section of the bulletin is based partly on notes taken by Professor N. O. Booth, formerly of the Station, on outfits owned by the following parties, to whom the Station is under obligations for information given and courtesies rendered: Messrs. S. W. Smith, H. E. Newing, and B. F. Morgan, of Albion; Albert Wood and George Callard of Carlton Station; J. B. Collamer and W. Smith of Hilton; A. B. Hull of the Friend Manufacturing Co., and Wm. Bugbee of Gasport; and Mr. Chapman of the Field Force Pump Co., Elmira.

Steam-power outfits are of two kinds, steam-engine outfits and steam-pump outfits. The steam-pump outfit differs from the steam-engine outfit, in that the engine is done away with and the steam power is applied directly to the piston of the pump. The outfit of Mr. T. B. Wilson (see p. 374 and Fig. 41), is an example of a steam-engine outfit and that of Albert Wood & Son (see p. 373 and Fig. 39) of a steam-pump outfit.

The engine is heavier than the steam pump but has the advantage that it can be detached and used elsewhere on the farm when not in use for spraying. Both are efficient and reliable. The standing objection to them is their great weight. More skill is required to operate them satisfactorily than is needed in operating the outfits previously described. In the opinion of many who have used them, it pays to have a power outfit if the area to be sprayed is over ten acres. Horizontal tanks are more commonly used with steam outfits. They are generally equipped with two leads of hose having one to four nozzles to each lead. There is an increasing tendency among purchasers of steam outfits to have the parts assembled by some experienced party.

Engines for spraying outfits are built to use either coal, wood or petroleum for fuel. The cost of the fuel used is generally regarded as too small to be taken into account. One orchardist estimates it at perhaps a peck of soft coal per tank of 250 gallons. Another esti-

mates it at from one to one and a half bushels a day according to the man who does the firing.

The capacity of boilers most commonly used at present is one and one-half horse-power, but a number of persons recommend two horse-power as better. One reason is, that with this power the pump runs steadier and requires less attention, and having a surplus of power there is less variation in pressure if the fire gets down a little or if cold water is taken into the boiler. The difference in weight is between the two boilers is little, and the difference in cost in the case of one make commonly used is only $5.

It may be remarked incidentally that the size of the air chamber appears to be of less practical importance in the case of the steam pump than it is in hand pumps, for in steam pumps the working of the machine is constant and steady, while in the case of hand apparatus there are frequent stops and great irregularity in the pressure.

Both brass-lined steam pumps and those that are bronze throughout are in use, and there is considerable diversity of opinion as to which is better. Some persons report that they have used the bronze pumps for several years without their wearing to such an extent as to damage them. But in the case of the brass-lined pump a worn cylinder can be supplied with a new lining at little expense. On the other hand brass-lined pumps have the defect that the orifices in and out of the cylinder are not lined with brass and the liquid is likely to attack the iron at these points, causing flakes to scale off and fall into the spray mixture thence getting into the nozzle and clogging it. On the whole, the bronze pumps are to be preferred.

CARE OF STEAM SPRAYING APPARATUS.

Certain practical difficulties in the operation of steam spraying outfits are met with. Some of these will now be considered.

Piston packing.—Complaint is made that the packing on the piston rod of the pump has to be replaced frequently, one man specifying

every three weeks. This is also true, of course, of hand pumps, but in this case the wearing does not proceed nearly as rapidly. This wearing may be prevented to a great extent by care in placing the packing, in selecting the quality used and also in selecting the lubricant. In our experience braided hemp packing thoroughly filled with tallow and graphite has given the best service on the piston rod.

The gland nut on the piston rod should not be screwed up too tight at first, as the heat generated by friction causes the packing to expand.

We have not yet found any satisfactory material for packing the piston itself. Manufacturers have sent out a leather packed piston which it is thought will do much to remedy the trouble of wearing. But so far as we know, this piston has not yet been sufficiently tested in practical work to permit of passing on its merits.

Oil cups.—There is frequent complaint also of trouble with oil cups. In fact some persons who have operated steam outfits declare they have more trouble with oil cups than with any other part of the outfit. This is a rather surprising experience. Of course, an oil cup needs reasonably skillful handling and the oil must be of good quality. Oil cups sometimes become clogged with thick matter in the oil or with particles of waste used in wiping. All dirt should be kept out of the cup. But nevertheless if it is rather cold the oil will get thick and not flow readily. In this case it should be warmed.

Cleaning boilers.—Most of the boilers used in spraying outfits are of the upright type and as such require peculiar management. Sediment and scale form in them quickly, and if not promptly removed, serious injury is likely to result. Flues where exposed to fire should be cleaned of soot every once or twice a week, and oftener if soft coal is used as fuel. A quarter of an inch of soot reduces efficiency nearly one-fourth. The tubes should be cleaned of sediment and lime as often as is necessary. When using some kinds of water a small quantity of soda ash is useful as a solvent for lime incrustations; with

other kinds of water, kerosene or a good boiler compound gives better results. These should be fed in small quantities at a time in the water supplied to the boiler. In cleaning the flues from sediment and lime incrustations the hand-hole plate should be removed and the settlings raked out. Then thoroughly rinse out with a stream of clean water from hose. Care should be taken when putting the hand-hole plate back in place to see that the gasket is properly fitted or serious leakage and loss of time may ensue. It is a good plan when the boiler has not been working for some time and the fire is low, as after the noon hour, to blow out about a gauge of water. By so doing much scale is prevented.

Low water.—If the water in the boiler gets low the sheets and flues are liable to be injured by overheating and the boiler itself may explode when taking in more water. Injectors do not always work at the pressure designated by the manufacturer, but may require considerably higher pressure to start. The inexperienced operator should not become frightened if the injector does not start at the pressure assigned to it by the manufacturer. After starting it may run on a lower pressure. In case of low water and failure of injector to work, it is better not to rake out the fire, but to smother it with earth or wet ashes, since stirring bituminous coal fire gives it more draft and makes the fire hotter for the time being.

General suggestions.—Try to carry a regular steam pressure, *i. e.*, if carrying 50 lbs. keep it near 50 lbs. all of the time. Keep water level as nearly even as possible. See that all of the appliances, such as safety valves, blow-off valves, fusible plugs, if any, are always in good working order and free from leakage. Never blow a boiler off suddenly or with a fire in it. Never allow a leak along a seam or around flues. When such occurs have a competent boiler-maker repair it immediately. Keep all valves well packed and all connections tight. Keep the ash box free from ashes, or burning and warping of the grate will follow.

INDIVIDUAL STEAM POWER OUTFITS.

Notes will now be given on a few steam spray outfits that are in actual use in the field.

Mr. S. W. Smith of Albion has an outfit which consists of a tank and steam pump. His boiler is of two horse-power. He says that some with whom he is acquainted have one-and-one-half horse-power boilers, and they give equally good satisfaction, but require more frequent firing. The cost of different parts of Mr. Smith's outfit was as follows: Wagon $37 without the bed, bed-piece $3, tank and agitator $15, boiler $43, pump $34, fittings about $10. The tank holds 250 gallons and the agitator is geared to the wheels. Mr. Smith uses two leads of hose and four Vermorel nozzels at the end of each lead.

Mr. H. E. Newing of Albion, who has had much experience in assembling various spraying outfits, uses the Electric Wheel Co.'s trucks, the Little Giant boiler and the Union steam pump. Mr. Newing estimates the cost of the fittings for an outfit at $18. The tank holds 230 gallons. It takes a good team to pull one of these outfits when full, and on soft ground there is danger of getting stalled. Mr. Newing advises the use of five- or six-inch tires.

Albert Wood & Son of Carlton Station have a rather heavy but very strong and good outfit. See Fig. 39. The trucks have high wheels behind and low ones in front, weigh 1000 pounds and cost $33. The bed pieces are connected by iron rods costing $5. The boiler and pump weigh 575 pounds. The tank holds 250 gallons.

The steam pump is the Union bronze and the boiler the Little Giant. The mounting of the boiler is unique in that it is hung by castings from the bed pieces, instead of resting on a platform. This arrangement serves for two purposes. In the first place it makes the mounting more solid and in the second place the outfit is relieved of the weight of a heavy platform. Brass fittings are used throughout. These are more expensive but they are undoubtedly more

serviceable than any other material that can be used. They have to be handled with greater care however, in being taken apart, because of the softness of the metal.

Outfits similar to this one are put out by Collard & Newing, Albion, N. Y.

Mr. J. B. Collamer of Hilton, N. Y., has an outfit (Fig. 40) having a common wagon truck with high wheels both before and behind and broad tires. The tank holds about 270 gallons and cost $22. The agitator is a screw agitator geared to the wheel. The outfit is not set on bed pieces but has semi-circular bolsters for the tank to rest in. This is required by the fact that the wheels are high and the outfit could not be turned readily if there were bed pieces close to the wheels. The pump is the Union steam pump and the boiler the Little Giant. The latter is set on a platform swung from the hind axle. The outfit weighs 2100 pounds and three horses are used on it.

Mr. W. I. Smith of Hilton has a one-and-one-half horse-power water-tube boiler, which is an unusual type for use in spraying outfits. In this type the water is in the tubes and the fire is on top of and around them. The boiler weighs only 206 pounds. It was made originally for an automobile and cost $50. It can be fired up very rapidly, a pressure of 50 to 100 pounds being obtainable in eight minutes. But the pressure goes down equally quick and the boiler has to be fired every five minutes. It also cost more than do other boilers.

Mr. T. B. Wilson of Halls Corners, N. Y., has an outfit (Fig. 41) consisting of a large upright cylindrical tank with a steam engine just in front of it, both mounted on a common farm wagon. Two lines of hose are used. Instead of a tower it is furnished with a seat fixed on top of the tank for the two men who handle the nozzles. The power spraying apparatus is from the Rochester Machine Tool Works. It consists of a one-horse power engine with one-and-a-half horse-power boiler, together with a small steam pump having a

capacity for delivering 300 gallons per hour under a pressure of 70 pounds. The agitator consists of two small blades similar to a propeller-wheel blade mounted on a bronze shaft connected with the engine by a flexible coupling. The speed can be varied at the pleasure of the operator. The price of this outfit complete is $250.

GASOLINE-POWER OUTFITS.

Gasoline possesses two advantages over steam as a source of power in a spraying outfit. These lie in the lightness of the outfits and the little attention they require while in operation. The objection to them is that their adaptation to spraying purposes has not yet been perfected, that is, they have not yet passed the experimental stage. They are, however, being rapidly perfected for spraying purposes by a number of competent manufacturers. In the opinion of users, gasolene outfits require somewhat more skill and ability to run them than do steam outfits, but this is not a serious objection.

The power in a gasoline engine is derived from the explosion of gas formed by mixing gasoline and air in proper proportions in the form of vapor. This vapor is drawn through a mixing valve into the combustion chamber by a forward movement of the piston. The return stroke of the piston compresses the gases thus drawn into the cylinder, and they are ignited at the proper time by an electric spark. The force of this explosion drives the piston forward again and the return stroke opens an exhaust valve and drives out the burned gases.

Gasoline engines are of two types, the upright and the horizontal. The upright engines offered for spraying purposes, so far as we have seen, are usually built on the general principle of the marine engine and are generally, though not always, operated on the two-cycle plan. They are generally run without governors, trusting to the work performed by the pump to keep the speed under control rather than to the friction of a paddle wheel in water. Of this type is the

Fairbanks-Morse engine used in the Goulds' gasoline outfit and shown in Fig. 42.

As an example of the horizontal engine the one used in the Lunt-Moss outfit may be instanced. (See Fig. 43.) This one is fed by pumping the gasoline from the base to the mixing chamber and has a governor to regulate the speed when the load varies. It is built on the four-cycle plan. One of these engines has been in use in an outfit at the Geneva Experiment Station this past summer. (See Fig. 44.) The engine is mounted behind a horizontal tank and on the same platform. It is entirely enclosed on sides and top—in the case of our outfit with canvas—to prevent any of the spray mixture falling on the engine. In our outfit the flaps of canvas are held down with snaps, admitting of ready access to the engine. The tank has a capacity of 250 gallons. The tower is readily removable by withdrawing four bolts, making the outfit handier for use among low trees. With the tower removed the top of the tank itself may be used as a spraying platform.

The Friend Mfg. Co. is putting out a gravity-feed horizontal engine regulated by sparking. It has direct connection with a Friend horizontal pump. Engine and pump are on a common base.

Our present opinion is that engines equipped with governors to regulate speed and fed by pumping from base to mixing chamber are probably better adapted to spraying purposes than those without governors and with gravity feed.

There has been so little practical field experience with gasoline engines in spraying operations that it is not practicable to make statements as to the relative merits of different makes. The following list includes all the manufacturers we know of who offer gasoline engines especially for use in spraying operations:

E. C. Brown & Co., Rochester, N. Y.
The Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.

Friend Mfg. Co., Gasport, N. Y.
Fuller & Cooper, Williamson, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Spray Pump Mfg. Co., Detroit, Mich.
Lunt-Moss Co., Boston, Mass.
Phelps Mfg. Co., Phelps, N. Y.
Spramotor Co., Buffalo and Toronto.

CARE OF GASOLINE ENGINES.

In running gasoline engines unlooked for difficulties are liable to come up at any time. Some of these are noticed below.

Heating of the bearings is usually caused either by lack of oil or by too tight adjustments, when the remedy is apparent. Be sure that all oil cups feed. Quite often these become clogged from thick matter in the oil or from waste used in wiping. The valves which admit the air and gas are usually constructed on the poppet type and are liable to become loosened or even to break. See that these are tight and all right. If the engine does not work right, first test the battery to see whether there is a strong enough electric current to ignite the gas. A weak current will not do that. Even when there is strong enough battery to furnish a good force of electricity there is sometimes trouble with the ignition which is usually occasioned by defective wiring or by crossed wires, or by sparking plug not making contact. In the last named case make the terminals clean and bright.

If the spark is furnished by the hammer-break device, possibly the points may be out of adjustment and consequently do not make contact, or the spring may have become weakened so that the sparking points are not snapped apart. The remedy for any of these is evident.

If the current is all right see whether the gasoline is being fed properly; then see that the sparker is not furred up, that is to say,

not gummed up. It should be kept clean else the spark will not be strong enough to ignite the gasoline. Be sure that the gasoline has no water in it. Even a few drops of water will stop the engine. Then if the engine is being properly fed and the current is strong enough to ignite the gas, there must be an explosion in the cylinder and the engine must go unless something is wrong with it other than the feed.

Back-firing may take place, in which case it is accompanied by sharp explosion and jet of flame from air inlet, which results from the charge igniting before entering the cylinder. This is usually caused by bad mixture of air and gas. A leaky inlet valve sometimes gives the same difficulty. If this occurs during compression it is usually due to wrong timing of the sparking mechanism or bad mixture of gas and air as above stated. See that the adjustments are corrected.

Any leak in a valve around a gas engine is sure to cause trouble, be it inlet or exhaust. If in the exhaust it will greatly lessen the efficiency of the engine. If in the inlet valve, new mixture is coming in all the time and will be forced back into the feed pipe during compression, together with a part of the burnt gasses and eventually this clogs the engine.

Keep all parts clean,—valves, sparking mechanism, etc. See that contact points are not corroded or furred with soot or carbon. Use plenty of oil. But if too much oil is used the sparker becomes corroded or furred.

Be sure that the air supply is properly regulated. If the air is cut off neither the vapor nor the liquid can be ignited; if too much air is present the mixture will not explode. If too much gasoline is admitted it burns with smoke and does not give good pressure. There should be just enough air to give sufficient oxygen to cause complete combustion of the gasoline vapor. With standard gasoline this varies in proportion from 6 to 1 to 10 to 1, according to conditions.

COMPRESSED-AIR OUTFITS.

Spraying outfits which use compressed air are of relatively recent introduction and have not been widely or thoroughly tested. They have the advantage of giving an evener pressure and the power forms are very much lighter than are other power outfits. But with some of them pressure cannot be maintained so high as with steam engines or gasoline engines. However, if a pressure of 50 pounds or more can be constantly maintained, such an outfit as this is in many respects superior to a hand pump outfit.

Further experiments are necessary to demonstrate the value of these outfits for use on high trees as compared with steam or gasoline outfits.

Compressed air outfits do not have mechanical agitators and do not appear to be well adapted for use with spraying mixtures containing heavy particles, such as paris green, unless some device is adopted for agitating the liquid by means of a jet of compressed air through the liquid from beneath, as is sometimes employed.

Compressed air sprayers are of two types, first, those in which only one chamber is used for both air and liquids, and second, those in which a separate chamber is used for each. Most of these outfits are of the former type and in these the tank is filled only about two-thirds full of liquid, the rest of the space being left for compressed air. But in outfits of the second type, represented by the Pierce-Loop outfits, the tank for the liquid is filled full.

In knapsack forms the tank is circular. It may be suspended from the shoulders or may be carried in the hand. One form is made by D. B. Smith & Co. It has an air pump attached to the tank. The same firm makes a knapsack sprayer, the power for which is furnished by squeezing a bulb just behind the nozzle.

The Rippley Hardware Co. makes a wheelbarrow outfit and knapsack outfit on the same principle. In both of these agitation of the liquid is provided for by the pumping in of the air at the bottom

of the tank. H. W. Henry of Laporte, Ind., makes the Utica high-pressure sprayer. This consists of two cylinders in connection with an air pump attached on the outside.

The Wallace Machinery Co., of Champaign, Ill., makes a compressed-air power-sprayer for use in connection with a common wagon tank. The machine consists of a pump and large air tank mounted on an oak frame. The pump is geared to a sprocket wheel on a wheel of the wagon. Air is pumped into the tank to forty or fifty pounds pressure, after which the liquid is pumped in and additional pressure thus secured, the pressure being thus brought up to 100 to 125 pounds. Pressure is also obtained in driving to the orchard, and is maintained by driving from one row to the next, or if the trees are large, by driving to alternate rows. The pump is of brass and adapted for pumping either air or liquid. Power is thrown on or off by a lever clutch. The outfit weighs only 275 pounds.

The Pierce-Loop Sprayer Co. of Northeast, Pa., has recently placed on the market a compressed-air rig (Fig. 45) that has been in use for several years. It consists of a boiler, engine and air-compressor centrally located, and two or three carts each carrying two fifty-gallon galvanized iron tanks, one of which is filled with the spray mixture, the other with compressed air, and the two tanks are connected with a pipe fitted with a valve. The cart outfit, which only is taken into the orchard, weighs but a few hundred pounds. One horse has no difficulty in handling it even over muddy or stony land or on a steep hillside. The rig has no working parts to be interfered with by low limbs or low-headed trees. As many lines of hose as the operator chooses to work may be used at the same time.

Of the practical working of this outfit Mr. A. I. Loop writes us as follows: "Of course our pressure is more even and better than can be had by any machine that pumps the liquid. It is steady, no jerks or sudden changes. We usually start with 130 to 150 pounds in the air tank and if there are no leaks in the air connections (we

never have trouble in this respect) the pressure at the finish will be about one-half of what we started with.

" Then when the cart returns to the loading station the connection is closed and the pressure in the air tank is saved, while the pressure in the mixture tank is used to blow it clean from sediment. Each tank is provided with a pressure gauge and the full pressure of the air tank is not let into the mixture, but only enough to raise it to forty or sixty pounds as may be wanted. It is not necessary to keep adjusting the connecting valve. The operator soon learns how much to open it to keep the pressure even in the mixture tank. If for any reason the operation of spraying is stopped for a few minutes the valve must be closed, to be reopened when work is commenced again."

To reach the tops of tall trees the Pierce-Loop Sprayer Co. has devised a stand pipe shown in Fig. 46. It consists of a piece of one-inch steam pipe of suitable length suspended free in a frame at the point where the hand lever is attached, as shown in the illustration. It is held upright by a box of stones attached to the bottom of the stand pipe. At the top are two short horizontal arms, each with a cluster of four nozzles at the end. Free rotation of the stand pipe is obtained through the hand lever, and vertical control by a hand rope. The stand pipe can be instantly pulled over so as to pass under limbs not less than five feet above the ground. The support is mounted on a sled which is attached by a chain and hook to the back of the spray cart.

W. H. Owen of Catawba Island, Ohio, has patented a pivotal standard (Fig. 45), for use with the Pierce-Loop outfit. It also consists of a piece of steam pipe pivoted to a base and held upright by the operator when in use. Along its sides at regular intervals are twelve nozzles, with which spray blasts are simultaneously given on approaching and passing a tree, by turning a valve.

Mr. W. E. Howard of Holley, N. Y., has a home-made outfit which

is unique and suggestive, although as now arranged it is open to objection on several points. The tank is partly filled with the spraying liquid, and then air pumped in until the requisite pressure is reached. The liquid is drawn from below for spraying. The tank holds about 150 gallons, is of galvanized iron and cost $41. It is mounted on a common wide tire wagon and set on bed pieces on bolster springs in front, but there are no springs behind. An inch pipe in the top is used for filling, and on the side of it a gauge is set. The outfit weighs about 1600 pounds with one man, the tank alone about 300 pounds. The pump was made by a local mechanic from an old Goulds pump. It is geared to one wheel and is of the oscillating cylinder type. The cylinder oscillates as the piston is raised and lowered. In practice about 130 gallons of liquid are put into the tank, and the pressure is raised to about fifty pounds before the pump is started. Power is kept up by spraying only one way through the orchard and then driving back to get up power. Two horses handle the outfit easily.

The Niagara gas sprayer (Figs. 47 and 48) consists essentially of a steel tank of 50 to 250 gallons capacity to contain the spray liquid, and a wrought iron tube containing carbonic acid gas compressed under a pressure of 1500 lbs. to the inch to supply power. The tubes of compressed gas are purchased from manufacturers in cities or large towns. When empty the tubes are returned. The tube only is shown in Fig. 47. The agitator is of the independent whirling paddle type and works through the top of the tank. The merits of the machine are lightness, entire saving of the power used in pumping and constant readiness of the power for use. But the machine has not been sufficiently tested to determine its value in the orchard. The outfit is sold separately or mounted as shown in the Fig. 48. It is supplied with or without kerosene-spraying attachment. The tower shown in Fig. 48 is of steel. An 8-foot tower is said to weigh only about 100 lbs. The railing around the platform of the tower

folds by unhooking two braces. The wagon is all steel. The front part of the platform is raised to allow the front wheels to cut under. On the front end of the platform in Fig. 48 is shown a tank pump used in filling the spray tank. One-and-two-horse outfits are also furnished with crop-sprayer attachments. In the latter, shown in Fig. 47, the agitator is worked by chain gearing from the wheel.

KEROSENE SPRAYERS.

The spraying of trees with either crude petroleum or kerosene for San José scale has been practiced in some quarters. Oil may be used either clear or emulsified with water. The treatment is generally effective against the scale but it is not entirely reliable as there is possibility of injuring the trees and sometimes they are killed by the oil. Difficulty lies in applying enough oil but no more than is needed to coat the tree evenly. In spraying pure oil, experienced sprayers endeavor to guard against applying an excess of the oil by having the smallest possible aperture in the nozzle cap. An emulsion of oil and water is somewhat safer. This application is made by specially designed oil and water pumps. These are simply adaptations of other spraying outfits and in most cases the oil attachment is readily detachable and the rest of the outfit can be used for spraying bordeaux mixture. The Deming Co. makes the Success kerosene bucket sprayer which differs from their Success bucket sprayer only in the addition of a can for oil. This is set inside the pail and is suitably connected with the pump.

Knapsack kerosene sprayers are constructed on the same principle, but generally the oil tank is outside and back of the main tank. Each tank may be fitted with independent pumps operated by a common lever or one pump may draw from both tanks.

Leggett & Bro. make a churn sprayer of various sizes from one to ten gallons capacity, especially for spraying oil and water and also for spraying bordeaux mixture. The tank is charged with an air-pump with which each sprayer is fitted.

Barrel outfits are constructed on the same principle as knapsack sprayers, but in these the oil tank is generally inside the barrel, except in the case of the Spramotor outfit.

An example of the former is Gould's Kerowater barrel outfit, shown in Fig. 49. The Spramotor outfit is shown in Fig. 50. In outfits having pumps each for oil and water the percentage of oil is varied by changing a pin in the lever of the pump of the oil tank at its attachment to the other lever. In outfits in which only one pump is used, the kerosene tank is connected with the pump by a suction pipe and the proportion of oil is controlled by a valve in the kerosene tank. This valve is connected with the indicator on top of the tank by a rod. The Goulds Mfg. Co. makes a large "Kerowater" in which a large horizontal water tank is used and the oil kept in a barrel on top of it. The pump is mounted on a tripod. The action is the same in principle as in the barrel "Kerowater" put out by the same company.

Very few, if any, of the pumps designed for spraying kerosene and water uniformly apply the desired proportion of oil as shown by the indicator. This may account for some of the injury that occurs when these pumps are used.

DUST SPRAYERS.

The term "dust sprayers" has recently come into popular use for designating those machines by which either insecticides or fungicides are applied to plants in the form of dry powder. The idea of treating plants with powders in this way is not new. The practice of applying sulphur, paris green or other dry powders, to field, garden and greenhouse crops either by means of bellows or of so-called "powder guns" has long been known both in America and in

foreign countries but till recently this method has rarely been used in orchards. Within the last few years dusting has come to be used as a substitute for spraying in orchard practice in certain portions of America. Not only are paris green, sulphur, etc., applied in this way but methods have been devised for preparing what is called dry bordeaux mixture which is dusted upon the trees as a substitute for the well known liquid bordeaux mixture.

The adherents of dust spraying are found mostly in Illinois, Missouri, Kansas and Arkansas. Its claim to attention lies in its great saving of labor and expense. An outfit consists simply of a machine mounted in a one-horse wagon. Only two men are needed to run the largest outfits, and a much larger area can be covered in the same time than by common spraying methods. The dust outfit is light and can be easily used in hilly orchards, and also on wet ground when heavy tanks of liquid could not easily be moved about the orchard. The apparatus applies the dry bordeaux mixture, paris green or other substances in the form of fine, dry powder. In this form insecticides are effective in combating the codling moth and other insects with biting mouth parts, but it is generally held by good authorities that the dry bordeaux mixture is less effective than the liquid bordeaux mixture for controlling fungus diseases, such as apple scab, etc.

The dust spray can probably be used to better advantage in the west, where the climate is comparatively dry, than in New York State, where the frequent rains would wash the dust off. Bordeaux mixture applied in the liquid form dries on and can often be seen on the leaves at the end of the season. So also does arsenate of lead.

Even in the west the advisability of the use of the dust spray is by no means generally accepted. In New York State the method has been little tested and barring its well-known use already referred to in the application of paris green, sulphur, etc., the attitude toward it is one of extreme conservatism. At the present writing the use of

bordeaux mixture in the form of dust spray is neither to be recommended nor condemned for New York State. It simply has not yet been tried to any extent.

Among dust sprayers, Leggett & Bro. of New York City make the Jumbo (Fig. 51), a machine of large capacity, and the Champion dry powder gun. A bellows form is put on the market by the Hillis Dust Spray Co., McFall, Mo. The Cyclone (Fig. 52) is a form made by the Dust Sprayer Co., Kansas City, Mo. The Whirlwind is still another kind. It is made by J. J. Kiser, Stanberry, Mo.

REPORT

OF

INSPECTION WORK.

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SOME FACTS ABOUT COMMERCIAL FERTILIZERS IN NEW YORK STATE.*

L. L. VAN SLYKE.

SUMMARY.

1. The farmers of New York State expend four and one-half million dollars a year for commercial fertilizers. Therefore, good business judgment should be used in such purchases. The object of this bulletin is to point out how better economy may be realized by purchasing plant-foods.

2. The general practice among farmers is to buy complete medium or low-grade fertilizers in preference to high-grade fertilizers. In high-grade goods, the cost of plant-food is considerably less than in fertilizers of lower grade.

3. Available phosphoric acid is cheapest in the form of dissolved rock (acid phosphate). Bone-meal furnishes a cheap source of phosphoric acid in less available form. Nitrate of soda is one of the cheapest sources of nitrogen, while bone is another. Nitrogen in the form of dried blood is rather high. Potash in the form of muriate is the cheapest source of potash. In mixtures of fertilizing materials, whether complete or incomplete, the plant-food usually costs more than in unmixed materials.

4. When purchasing mixed fertilizers, farmers are advised to purchase only high-grade goods, and then to make a commercial valuation to compare with the selling price. Even in high-grade

* A reprint of Bulletin No. 230.

goods, the selling price should not exceed the commercial valuation by more than $5.

5. For greatest economy, farmers are advised to purchase unmixed materials and do their own mixing; or, in the case of clubs, several farmers can purchase their unmixed materials and hire a fertilizer manufacturer to do the mixing for them.

6. Illustrations are given of three types of plant-food mixtures: (a) A mixture with phosphoric acid high in amount in relation to nitrogen and potash; (b) a mixture of high-grade, in which the potash is high in amount in relation to nitrogen and phosphoric acid; (c) a mixture of high-grade, containing nitrogen, phosphoric acid and potash in quantities more nearly equal than in the other mixtures.

7. A general review is given covering the work of the Station in collecting and analyzing fertilizers during the last five years. In general, it is shown that the number of manufacturers of commercial fertilizers and of brands of fertilizers has decreased since 1899, owing to the requirement of a license fee of $20 for each brand offered for sale. In respect to composition, the average variation from year to year has been within narrow limits. The number of brands found below guarantee has steadily decreased. The average selling price per ton has also gradually decreased and also the difference between the selling price and commercial valuation.

INTRODUCTION.

The farmers of New York State expend for plant-food in the form of commercial fertilizers about four and one-half million dollars a year. Only two or three other states show a larger annual expenditure in this line. While many dairy farmers depend mainly or altogether upon farm-produced or domestic manures as sources of plant-food, all who most profitably and continuously raise cereals, hay and forage crops, potatoes, fruits, flowers, plants, nursery stock, garden crops, hops, tobacco, sugar beets, crops under glass, etc., are compelled to use liberal quantities of commercial fertilizers. The amount of these materials used differs with the character of the agriculture in different sections of the State. The following data, taken from the last U. S. census report, are of interest in this connection as indicating in what portions of the State the largest amount of money is expended for commercial fertilizers:

Long Island (Counties of Nassau, Queens and Suffolk)	$1,241,280
Monroe County	214,000
Erie County	186,370
Cayuga County	131,260
Oneida County	112,630
Onondaga, Ontario, Wayne, Ulster, Chautauqua, each from $102,000 to	110,000

These 12 counties use about one-half of the commercial fertilizers used in the entire State.

In view of these large expenditures, it becomes a matter of economic importance to the many farmers who use materials of this class to exercise good business judgment in the purchase of their plant-food. It is a prominent fact that a very large proportion of the commercial fertilizers used in New York is in the form of so-called complete fertilizers, that is, mixtures containing compounds of nitrogen, phosphoric acid and potash. These vary greatly in composition and in price.

It is the object of this bulletin to call attention to such differences in cost of plant-food as we have actually found in the case of various commercial fertilizers sold in this State during 1902. There are certain noticeable facts which should be made known to

purchasers of complete fertilizers, in order that in the future they may buy more economically than they have in the past. The data presented are based upon the analyses of samples collected during the spring and summer of 1902, contained in Bulletin No. 216.

DISCUSSION OF DATA.

CLASSIFICATION OF FERTILIZERS.

For the purpose of the study presented in the following pages, we have made an arbitrary division of complete fertilizers into four separate classes, based upon their commercial valuation, that is, the price at which the separate unmixed materials in one ton of fertilizer could be purchased for cash at retail at the seaboard. Our classification is as follows:

1. *Low-grade fertilizers,* those having a commercial valuation of less than $16 a ton.

2. *Medium-grade fertilizers,* those having a commercial valuation greater than $16 and less than $20 a ton.

3. *Medium high-grade fertilizers,* those having a commercial valuation greater than $20 and less than $25 a ton.

4. *High-grade fertilizers,* those having a commercial valuation greater than $25 a ton.

We will now study comparatively these four classes of complete fertilizers from several different points of view.

DISTRIBUTION OF FERTILIZERS AMONG DIFFERENT CLASSES.

Taking the complete fertilizers, whose analyses are given in Bulletin No. 216, we find that, of the 688 samples collected, they were distributed among the four different classes, as follows:

Low-grade	171,	or 25	per ct. of all.
Medium-grade	236,	or 34.3	per ct. of all.
Medium high-grade...	163,	or 23.7	per ct. of all.
High-grade	118,	or 17	per ct. of all.

Using these data as a basis, we are justified in saying that, of the complete fertilizers sold in this State during 1902, nearly 60 per ct. was medium or low-grade in character. Only about one-sixth could be classed as strictly high-grade in composition. Thus, the general tendency among farmers is to purchase complete fertilizers that are not even medium high-grade in character.

COMPOSITION OF FERTILIZERS IN DIFFERENT CLASSES.

If we compare our four different classes of complete fertilizers in respect to the average amounts of nitrogen, available phosphoric acid and potash contained in them, we have the following table:

Composition of Different Grades of Fertilizers.

Class of fertilizers.	In 100 pounds of fertilizer.			
	Pounds of nitrogen.	Pounds of available phosphoric acid.	Pounds of potash.	Pounds of total plant-food.
Low-grade	1.22	8.18	2.60	12.00
Medium-grade	1.70	9.10	3.48	14 28
Medium high-grade	2 47	8.82	6.02	17 37
High-grade	4 00	8.36	7.22	19.60

In the fourth column, under the heading "pounds of total plant-food," we give the sum of the nitrogen, available phosphoric acid and potash. We notice the following points in connection with this table:

(1) The percentage of phosphoric acid does not vary greatly in the different classes of fertilizers.

(2) The percentage of nitrogen and of potash increases in the higher grades.

(3) The total amount of plant-food in 100 pounds of fertilizer increases in the higher grades, this increase being due to increase of nitrogen and potash.

(4) Representing the amount of nitrogen in each grade of fertilizer as 1, we have the following proportions of available phosphoric acid and potash in the different grades:

	Nitrogen.	Available phosphoric acid.	Potash.
Low-grade	1	7	2
Medium-grade	1	5.5	2
Medium high-grade	1	3.5	2.5
High-grade	1	2	1.8

This form of statement clearly brings out the fact that fertilizers of different grades differ not only in respect to the amounts of plant-food contained, but that the different elements of plant-food bear a different ratio to each other in the different grades. Thus, as the grade grows higher, the proportion of phosphoric acid to nitrogen grows less, or, stated another way, the proportion of nitrogen to phosphoric acid increases. In low-grade fertilizers, there is 7 times as much phosphoric acid as nitrogen, while in high-grade goods there is only twice as much. While the ratio of nitrogen to potash varies, the variation is not great.

(5) The ratio of nitrogen, phosphoric acid and potash found in high-grade fertilizers approximates much more closely the ratio found in plants than does the ratio existing in low-grade goods.

RELATION OF SELLING PRICE TO COMMERCIAL VALUATION.

In the table below, we give the average actual selling price and the average commercial valuation in the case of each grade of fertilizers, and also the excess of selling price over the commercial valuation. As the commercial valuation represents the average retail price of the separate unmixed materials contained in one ton of fertilizer at the seaboard, the excess of selling price above commercial valuation represents the cost of mixing, the freight, profits, and cost of business.

SELLING PRICE AND COMMERCIAL VALUATION OF DIFFERENT GRADES OF FERTILIZERS.

	Low-grade.	Medium-grade.	Medium high-grade.	High-grade.
Selling Price.				
Lowest	$16 00	$18.00	$20.00	$25 00
Highest	34.00	30.00	40.00	44.00
Average	23.00	24 85	28.30	32.80
Commercial Valuation.				
Lowest	9.51	16.01	20.00	25.07
Highest	15 98	19.90	24 90	37 25
Average	14 42	17.70	22.15	27.70

SELLING PRICE AND COMMERCIAL VALUATION ETC.—(*Concluded.*)

	Low-grade.	Medium-grade.	Medium high-grade.	High-grade.
Difference between Selling Price and Commercial Valuation.				
Lowest	3 60	1.57	0.62	7 25*
Highest	21.74	12.53	15 20	10.30
Average	8.58	9.15	6.15	5.10

*Commercial valuation exceeds selling price.

A study of this table suggests several points of interest.

(1) We notice that the selling price varies greatly for any one grade of goods. For example, in the low-grade goods, the lowest selling price was $16 a ton, and the highest $34, a tremendous difference when we consider that there was a difference of not more than $6.50 in their actual plant-food value. In all the grades we find a variation in selling price entirely disproportionate to the difference in value of the plant-food contained in them. In the high-grade goods, we find the difference somewhat less marked but still unreasonably great.

(2) The excess of selling price over commercial valuation is greater in low-grade and medium goods than in high-grade goods; in other words, the high-grade goods sell, on an average, nearer to their actual plant-food value than do low-grade goods.

(3) While the data contained in the preceding table do not show it, our records show that the same brand of goods is often sold by different agents at prices differing as much as $5 to $8 a ton and this, too, under circumstances that do not appear to justify any such difference. In some cases the question of price appears to depend, not upon the value of the goods, but upon the judgment of the seller as to how much he can get.

COST OF ONE POUND OF PLANT-FOOD IN DIFFERENT GRADES.

The difference in cost of plant-food in high-grade and low-grade fertilizers can best be brought out by showing the cost of one pound of plant-food as purchased by the consumer. In the following table we state the lowest, highest and average cost of one pound of nitrogen, of available phosphoric acid and of potash as actually purchased by consumers in 1902.

COST OF ONE POUND OF PLANT-FOOD IN DIFFERENT GRADES OF FERTILIZERS.

	Low grade.	Medium grade.	Medium high-grade.	High grade.
Cost of one pound of Nitrogen.	*Cents.*	*Cents.*	*Cents.*	*Cents.*
Lowest	20	17.9	17	13 3
Highest	36.8	28 3	26	26 0
Average	26.3	23.2	21	19.6
Cost of one pound of Available Phosphoric Acid.				
Lowest	6.1	5.4	5.1	4.25
Highest	11.1	8 6	8.1	7.9
Average	8.0	7 0	6.4	6.0
Cost of one pound of Potash.				
Lowest	5.2	4 6	4.4	3.4
Highest	9 5	7.3	6 9	6.7
Average	6.8	6.0	5 4	5.0

From these data, we readily see the truth of the following statements:

(1) The cost of one pound of plant-food, whether nitrogen, phosphoric acid or potash, is greatest in low-grade, and least in high-grade, fertilizers. One purchaser of low-grade goods paid 36.8 cents a pound for nitrogen, while the highest price paid in high-grade goods was 26 cents, which is less than the average paid for nitrogen in low-grade goods. The least amount paid for one pound of nitrogen in low-grade goods was 20 cents, in high-grade goods 13.3 cents. Similar relations hold good in respect to the other elements of plant-food.

(2) In general, the higher the grade of goods, the lower the cost of each pound of plant-food.

THE COST OF PLANT-FOOD IN MIXTURES CONTAINING PHOSPHORIC ACID AND POTASH.

Considerable quantities of commercial fertilizers are sold in the form of mixtures of dissolved phosphate rock (acid phosphate) and muriate of potash, under such names as "alkaline bone and potash," "bone and potash" "dissolved bone and potash," "soluble bone and potash," "alkaline dissolved bone," "acidulated bone and potash," "alkaline phosphate," and vari-

ous other special names. For some years these fertilizers have been popular with many farmers. As they contain no nitrogen, they can be sold at prices that look cheap in comparison with the prices of complete fertilizers. Many farmers consider cost only and not composition in purchasing fertilizers.

In 1902 we found in the market 58 different brands of this kind of fertilizer. In average composition, these mixtures contained 11.10 per ct. of available phosphoric acid and 4 per ct. of potash. The selling price varied from $13.50 to $26 a ton, averaging $19.17, while the commercial valuation varied from $4.60 to $19.01, averaging $14.50. The average selling price exceeded the average commercial valuation $4.67 a ton; in one case, the difference was as great as $13.40. The cost of one pound of available phosphoric acid varied from 4.3 cents to 19.5 cents and averaged 6.6 cents. The cost of one pound of potash varied from 3.7 cents to 16.5 cents and averaged 5.6 cents.

From the foregoing data, we conclude:

(1) That, in cost of plant-food, the lowest prices compared favorably with the lowest prices found in complete high-grade mixtures, while the highest prices were greatly in excess even of the highest prices found in low-grade complete fertilizers. The average prices were somewhat above those found in medium high-grade complete fertilizers.

(2) That the selling prices of mixtures of acid phosphate and potash salts are subject to much wider variations than in complete goods and average dearer than complete high-grade goods.

COST OF PLANT-FOOD IN THE FORM OF ACID PHOSPHATE.

Most of the phosphoric acid in the market is dissolved rock, no matter under what name sold, especially if it contains no guaranteed nitrogen. Real dissolved bone and bone-black are comparatively rare. In 1902 we collected 34 different brands of goods containing only phosphoric acid compounds. In these brands, the available phosphoric acid varied from 11.42 to 17.10 per ct., averaging 14.56 per ct. The selling price varied from $13 to $25 a ton and averaged $14.95. The commercial valuation varied from $11.42 to $17.10 and averaged $14.56 a ton. In one case, the selling price exceeded the commercial valuation $13.58. The cost of one pound of available phosphoric acid

varied from 4.4 to 11 cents and averaged 5.1 cents. On an average, the available phosphoric acid cost less in this form than in mixed goods, but the variation was much greater than it should be. If we did not have a record of the facts, it would be difficult to believe that any seller of fertilizers could bring himself to charge $25 a ton for plain acid phosphate. It is inconceivable that any circumstances should exist that could justify such an enormous overcharge.

COST OF PLANT-FOOD IN THE FORM OF BONE-MEAL.

In the case of 23 different brands of bone-meal, the nitrogen varied from 1.26 to 5.56 per ct. and averaged 3.32 per ct.; the total phosphoric acid varied from 13.42 to 28.48 per ct. and averaged 23.48 per ct. The selling price varied from $21.50 to $35 and averaged $28.50; the commercial valuation varied from $26.28 to $35.75 and averaged $28.74, exceeding the selling price somewhat. The cost of one pound of nitrogen in bone-meal varied from 11.5 to 32 cents and averaged 14.9 cents; the cost of one pound of available phosphoric acid varied from 3.1 to 8.6 cents and averaged 3.96 cents. As compared with the cost of nitrogen and phosphoric acid in complete fertilizers, these forms of plant-food are considerably cheaper when purchased in bone, but it should be kept in mind that the phosphoric acid in bone-meal is considerably less readily available than in the form of dissolved rock. Where moderately slow action of phosphoric acid is desired, bone-meal may answer the purpose, but for rapid action, one should use the readily soluble forms.

COST OF NITROGEN IN NITRATE OF SODA.

In the samples of nitrate of soda examined by us in 1902, the percentage of nitrogen varied from 15.21 to 16.20, averaging 15.77. The selling price varied from $42 to $48.50, averaging $44.12. The commercial valuation varied from $45.63 to $48.60, averaging $47.30, which was considerably in excess of selling price. The cost of one pound of nitrogen in this form varied from 13 to 15 cents and averaged 13.9 cents. This was much cheaper than the cost of nitrogen in the form of complete fertilizers.

COST OF NITROGEN IN DRIED BLOOD.

In the samples of dried blood analyzed by us in 1902, the percentage of nitrogen varied from 8.72 to 11.88, averaging 10.38. The selling price varied from $35 to $40, averaging $38.33. The commercial valuation varied from $28.78 to $39.20, averaging $34.26. The cost of one pound of nitrogen varied from 14.8 to 22.9 cents, averaging 18.5 cents. This makes the price of the nitrogen of dried blood higher than that in nitrate of soda and bone-meal but somewhat cheaper than nitrogen in complete fertilizers.

COST OF POTASH IN MURIATE OF POTASH.

The percentage of potash was found to vary from 49.06 to 52.04, averaging 50.46. The selling price varied from $46 to $48 and averaged $46.75. The commercial valuation varied from $41.70 to $44.23, averaging $42.89. The cost of one pound of potash varied from 4.4 to 4.9 cents and averaged 4.6 cents. In average price, potash in the form of muriate was cheaper than in the highest grade mixed goods.

TABULATED GENERAL SUMMARY.

In the table following, we give a general summary of the data that have been presented, showing the cost of one pound of plant-food in different forms to consumers.

COST OF ONE POUND OF PLANT FOOD TO CONSUMERS.

	Lowest.	Highest.	Average.
NITROGEN IN	*Cents.*	*Cents.*	*Cents.*
Low-grade complete fertilizers	20	36.8	**26.3**
Medium-grade complete fertilizers	17.9	28.3	**23.2**
Medium high-grade complete fertilizers	17	26	**21**
High-grade complete fertilizers	13.3	26	**19.6**
Dried blood	14 8	22.9	**18.5**
Bone-meal	11.5	32	**14.9**
Nitrate of soda	13	15	**13.9**
PHOSPHORIC ACID IN			
Low-grade complete fertilizers	6.1	11.1	**8.0**
Medium-grade complete fertilizers	5.4	8.6	**7.0**
Medium high-grade complete fertilizers	5.1	8.1	**6.4**
High-grade complete fertilizers	4.25	7.9	**6.0**
Phosphoric acid and potash mixtures	4.3	19 5	**6.6**
Acid phosphate or dissolved rock	4.4	11.0	**5 1**
Bone (total)	3.1	8.6	**3.96**

COST OF ONE POUND OF PLANT FOOD TO CONSUMERS.—(*Concluded.*)

	Lowest.	Highest.	Average.
POTASH IN	*Cents.*	*Cents.*	*Cents.*
Low-grade complete fertilizers	5.2	9.5	6.8
Medium-grade complete fertilizers	4.6	7.3	6 0
Medium high-grade complete fertilizers	4.4	6 9	5.4
High grade complete fertilizers	3.4	6 7	5.0
Phosphoric acid and potash mixtures	3.7	16 5	5 6
Muriate of potash	4.4	4.9	4.6

PURCHASE OF PLANT-FOOD.

The data contained in the preceding tables afford a good basis for calling the attention of farmers to certain facts and for making suggestions connected with the purchase of plant-food.

(1) *Farmers are advised, before purchasing, to obtain for themselves prices at which they can actually buy plant-food.* It should be kept in mind that the prices given as trade-values in Station bulletins are only averages and do not represent accurately all conditions of the market without regard to time or place. Actual trade-values necessarily vary with localities and with different times of the year. The true values to use in making a commercial valuation of plant-food are those figures which represent the actual prices at which the farmer can purchase the elements of plant-food at a given time. Quotations should be obtained by making inquiries of several manufacturers, asking at what prices they will furnish the specific forms of plant-food that one wishes to use. The prices thus found enable the farmer to make out his own schedule of valuations and they apply accurately to his special conditions.

The following parties have paid license fees permitting them to sell the unmixed materials indicated during 1903:

Nitrate of soda.

Bowker Fertilizer Co., 68 Broad St., New York City.
E. Frank Coe Co., 135 Front St., New York City.
The American Agricultural Chemical Co., 26 Broadway, New York City.

E. Aspinall, 100 Beekman St., New York City.

Muriate of potash.

Bowker, Coe, Am. Agr. Chem. Co.

Kainit.

Am. Agr. Chem. Co.

Such materials as bone and acid phosphate can be purchased from any large dealer in fertilizers.

(2) *Shall farmers purchase mixed fertilizers or unmixed materials?*

It has been represented to farmers that peculiar virtues are imparted to the elements of plant-food by proper mixing and that this proper mixing can be accomplished only by means not at the command of farmers. Such statements are misrepresentations, based either upon the ignorance of the person who makes them or upon his anxiety to sell mixed goods. Nitrate of soda, for illustration, does its work in plant nutrition in exactly the same manner whether it is added to the soil as part of a mixture or whether the ingredients of the mixture are applied separately. The availability of plant-food is not usually affected by mixing. Other conditions determine whether a fertilizer shall be applied in mixed form or in separate materials.

As to the ability of farmers to mix their own fertilizers, no doubt exists except in the minds of those who desire to sell goods ready mixed. The main consideration that presents itself as between purchasing mixed and unmixed forms of plant-food is the question of economy. What do the figures published above show on this point?

(*a*) Each pound of nitrogen in mixed fertilizers cost the farmer in this State last year over 20 cents, on an average, while the schedule price is 16½ cents. Hence, on an average, farmers paid for their nitrogen in mixed goods, at least 25 per ct. more than it would have cost them in unmixed forms.

(*b*) Each pound of available phosphoric acid in mixed fertilizers cost the farmer over 6 cents and in dissolved phosphate, purchased from retail dealers, it cost about 5 cents; while, purchased at schedule prices, it would be 4½ cents; but as a matter of fact farmers were able to purchase available phosphoric acid in the form of dissolved rock for even less.

In this connection, it may be well to state that soluble phosphoric acid has the same value, pound for pound, whatever its source. At present dissolved rock is the cheapest source and this is the form in which farmers should buy phosphoric acid, if they desire to receive the largest amount of actual plant-food for their money.

(*c*) Each pound of potash, mostly in form of muriate, cost the farmer nearly 6 cents in mixed fertilizers, while in one sample of muriate purchased, the cost was 4.4 cents.

It can readily be seen that, in point of economy, under the conditions actually prevailing last year, farmers could buy their plant-food at much lower prices in unmixed forms than in mixed goods.

(3) *How can plant-food be purchased most cheaply?*

If each farmer by himself buys plant-food, he can undoubtedly secure most economical results by getting unmixed materials. Still better prices can be realized by co-operation. This method is being effectively carried out in many parts of the State by granges and by farmers' clubs. The unmixed materials are purchased in quantity and distributed to individuals, each of whom mixes his own materials; or the goods are mixed by some manufacturer of fertilizers in accordance with specifications calling for a certain formula and certain ingredients, the mixed goods being delivered to a purchasing agent, who distributes them to individual consumers. Such methods always depend upon cash payment and usually result in the most economical purchase of plant-food.

(4) *Purchasing mixed fertilizers.*

In purchasing mixed fertilizers, farmers should always make a commercial valuation based on the guaranteed composition of the fertilizer and compare this with the selling price. The difference should not exceed $5. Taking the precaution to compare the commercial valuation and the selling price, it is always wise to purchase high-grade fertilizers. These should furnish plant-food at a less cost than fertilizers of lower grade, owing to lower cost of freight per pound of actual plant-food and lower cost of sacking, etc.

ILLUSTRATIONS OF PLANT-FOOD MIXTURES.

For illustration we will give a few examples, showing how we can prepare different mixtures by using the same materials in varying quantities.

Mixture No. 1.

250 pounds nitrate of soda, containing 37.5 pounds of nitrogen,
200 pounds cottonseed-meal, containing 12.5 pounds of nitrogen,
1,300 pounds acid phosphate, containing 180 pounds of available phosphoric acid,
120 pounds muriate of potash, containing 60 pounds of potash,
130 pounds land plaster or other inert material,

This gives us a mixture containing in one ton about 50 pounds of nitrogen, 180 pounds of available phosphoric acid and 60 pounds of potash or, on the basis of 100 pounds, 2.5 per ct. of nitrogen, 9 per ct. of available phosphoric acid and 3 per ct. of potash. In this mixture, we have relatively small amounts of nitrogen and potash in relation to phosphoric acid. The cottonseed-meal, besides furnishing some plant-food, enables us to make a mixture of good mechanical properties that behaves well in a drill.

Mixture No. 2.

300 pounds nitrate of soda,
300 pounds cottonseed-meal,
500 pounds bone-meal,
500 pounds acid phosphate,
400 pounds muriate of potash;

or, using only acid phosphate, we may have the following:

400 pounds nitrate of soda,
300 pounds cottonseed-meal,
900 pounds acid phosphate,
400 pounds muriate of potash.

In this mixture, we have about 4 per ct. of nitrogen, 6 per ct. of available phosphoric acid and 10 per ct. of potash, in which the potash is high relative to the other constituents. It will be seen that this mixture differs from the first in being of higher grade, particularly in respect to nitrogen and potash. The use of bone in place of part of the acid phosphate, as indicated in one

form of mixture No. 2, may be found desirable in the case of crops whose growth covers a comparatively long period, when a portion of the phosphoric acid is not needed at once.

Mixture No. 3.

400 pounds nitrate of soda,
300 pounds cottonseed-meal,
500 pounds bone-meal,
500 pounds acid phosphate,
300 pounds muriate of potash;

or, using only acid phosphate, we have the following:

475 pounds nitrate of soda,
275 pounds cottonseed-meal,
950 pounds acid phosphate,
300 pounds muriate of potash.

In this mixture we have about 5 per ct. of nitrogen, 7.5 per ct. of available phosphoric acid and 7.5 per ct. of potash; the nitrogen is high in relation to phosphoric acid and potash, and also the three elements of plant-food are in proportions more nearly equal than in the preceding mixtures. This is also a high-grade mixture.

These three mixtures are given chiefly to illustrate different types of plant-food mixtures that may be found in the market.

GENERAL REVIEW OF RESULTS OF THE WORK OF THE FERTILIZER DEPARTMENT FOR FIVE YEARS.

In tabulated form, we present below some of the results that have been accomplished during the last five years by this Station in its work of collecting and analyzing commercial fertilizers.

NUMBER OF MANUFACTURERS AND BRANDS OF COMMERCIAL FERTILIZERS.

	1898.	1899.	1900.	1901.	1902.
Number of manufacturers	193	190	113	82	71
Number of different brands offered for sale	1,900	2,268	600	550	590
Number of samples collected by Station	1,427	1,004	638	963	924
Number of different brands collected and analyzed	901	776	450	465	450

It will be noticed that the number of manufacturers of commercial fertilizers decreased very largely in 1900 as compared with preceding years. This marked decrease was due to a new provision of the fertilizer law, first taking effect in 1900, requiring manufacturers to pay a license fee of $20 on each brand offered for sale in this State. Small mixers in the State discontinued their business and manufacturers outside of New York, whose business did not warrant the payment of the license fee, withdrew their goods and business. The number of manufacturers was still farther apparently decreased in 1901 by the combination of over 20 companies under one name.

The most marked effect of the requirement of a license fee for each brand was to reduce the number of brands offered for sale. The increase of different brands had gone on rapidly from a few hundred, until in 1899 it reached the phenomenal number of 2,268. This number fell at once in 1900 to 600 and has since remained between that number and 550. The multiplication of brands by manufacturers had become a most serious abuse, entailing an immense amount of work and expense on the Station in the collection and analysis of the different brands. It was possible to reach this abuse only by the requirement of a license fee.

THE COMPOSITION OF FERTILIZERS ANALYZED.

	1898.	1899.	1900.	1901.	1902.
Nitrogen found, per ct.	2.20	1.97	2.16	2.01	2.24
Nitrogen found above guarantee, per ct.	0.14	0.14	0.10	0.12	0.32
Available phosphoric acid found, per ct.	8 65	8.80	8.90	8.80	8.62
Available phosphoric acid found above guarantee, per ct.	1.00	0 93	1 28	1.13	0.91
Potash found, per ct.	4.91	4.76	4.84	4.47	4.67
Potash found above guarantee, per ct.	0.24	0.28	0 41	0.34	0.22
Water-soluble nitrogen found, per ct.	0.94	0 80	0.89	0.87	0.93
Water-soluble phosphoric acid found, per ct.	5.08	5.40	5.52	5.04	5 46

From the data embodied in this table, it is readily seen that there has been comparatively little variation in the average composition of fertilizers from year to year. The amounts of nitrogen, phosphoric acid and potash above guarantee have run within comparatively narrow limits. The data show that goods

have been kept up to about the same average without any deterioration.

NUMBER OF BRANDS BELOW GUARANTEE.

In the following table, we indicate the number of brands falling more than one-half of one per cent. below guarantee during the past five years:

	1898.	1899.	1900.	1901.	1902.
Number of brands more than 0.5 per ct. below guarantee in nitrogen	14	12	8	6	2
Number of brands more than 0.5 per ct. below guarantee in available phosphoric acid	33	24	11	6	7
Number of brands more than 0.5 per ct. in potash	22	58	20	16	30

We notice that from 1898 on there has been a marked continuous decrease in the number of brands that were more than one-half of one per cent. below guarantee. This indicates that manufacturers are doing more uniform work in mixing their goods. The showing is a very satisfactory one.

PRICES OF COMMERCIAL FERTILIZERS.

	1898.	1899.	1900.	1901.	1902.
Average selling price, per ton	$27.65	$26 07	$27.27	$25.71	$26.14
Average commercial valuation	18.52	18.06	19.72	19.81	20.76
Excess of selling price above commercial valuation	9.13	8.01	7.55	5.90	5.38
Cost of one pound of nitrogen in mixed fertilizers	21 cts.	20.2 cts.	21.4 cts.	20.8 cts.	20.8 cts.
Cost of one pound of available phosphoric acid in mixed fertilizers	6.5 "	6.1 "	6.2 "	6.2 "	6.1 "
Cost of one pound of potash in mixed fertilizers	6.75 "	6.1 "	6.2 "	5.9 "	5.7 "

We notice that there has been a general tendency in the direction of lower average selling prices and an increase in commercial valuations, resulting in a smaller difference, from year to year, between the selling price and commercial valuation. There has also been a slight tendency in the direction of lower prices for each pound of plant-food.

INSPECTION OF FEEDING STUFFS*.

W. H. JORDAN AND F. D. FULLER.

SUMMARY.

(1) One hundred manufacturers have licensed one hundred and fifty-one brands of feeding stuffs for the year 1903.

(2) Five hundred eighteen samples of feeding stuffs, officially collected from October, 1902, to February, 1903, have been analyzed.

(3) No adulteration was observed among the cotton seed and linseed meals, gluten products and brewers and distillery residues, as shown by the official samples. Corn cobs were shown to be present in three brands of licensed feeds, in two samples of unlicensed bran and in one sample sold as pure corn meal. Several proprietary feeds were found, as usual, to be made up in part of oat hulls.

(4) Many samples of wheat offals, bran, middlings and the same mixed, were found to be unadulterated and of good quality. The same can be said of numerous samples of corn and oats ground together.

(5) The markets are offering many inferior feeding stuffs. At the same time, the great bulk of commercial cattle foods available to buyers are unadulterated and of good quality.

INTRODUCTION.

The feedings stuffs law provides for the annual analysis of the various feeds found on sale in New York, and "the results of the analysis, together with such additional information as circumstances advise, shall be published in reports or bulletins from time to time."

*A reprint of Bulletin No. 240.

The feeds which are included in the law are: Linseed meal, cottonseed-meal, pea-meal, cocoanut meal, gluten meal, gluten feed, maize feed, starch feed, distiller's grains, brewer's grains, malt sprouts, hominy feed or chop, cerealine feed, rice meal, oat feed, corn and oat chop, ground beef or fish scraps, mixed feed, and all other materials of similar nature.

All other materials not included in the above list, such as hay, and straw, and the entire grains of the various cereals, either whole or ground into meal, also bran and middlings from wheat, rye and buckwheat when sold as such, can be handled legally without the payment of a license fee.

During the present year one hundred manufacturers or jobbers have registered the required guarantees and paid the license fee on one hundred and fifty-one brands of feeding stuffs to be placed on sale in New York State in 1903.

The brands named in the following table (I), may be handled legally during the present year and consumers may purchase these feeds with a fair knowledge concerning their general character:

TABLE I.—MANUFACTURERS AND IMPORTERS WHO HAVE COMPLIED WITH THE NEW YORK STATE FEEDING STUFFS LAW FOR THE YEAR 1903, WITH A LIST OF BRANDS SO GUARANTEED AND THE GUARANTEES.

License number.	Manufacturer or jobber.		Name of feed.	Guaranteed.	
	Name.	Address.		Protein.	Fat.
				Per ct.	Per ct.
293	Acme Milling Co.,	Olean,	Acme feed,	8.5	5.5
346	Adikes, J. & T.,	Jamaica,	Ground feed,	8.75	3.0
374	Alma Sugar Co.,	Alma, Mich.,	Dried molasses-beet-pulp,	6.56	0.48
360	American Cereal Co., The,	Chicago, Ill.,	American poultry food,	14.0	4.5
	" " "	" "	Quaker dairy feed,	14.0	3.5
	" " "	" "	Corn oats and barley feed,	13.0	5.0
	" " "	" "	Schumacher's stock feed,	13.0	5.0
	" " "	" "	"C" feed,	9.0	4.0
	" " "	" "	Victor corn and oat feed,	9.0	4.0
	" " "	" "	Vim oat feed,	7.5	2.75
292	American Cotton Oil Co., The,	New York,	"Prime" cottonseed meal,	43.0	9.0
285	American Hominy Co.,	Chicago, Ill.,	Hominy feed,	10.24	7.72
	" " "	" "	Maizeline,	14.81	8.76
288	American Linseed Co.,	New York,	Oil meal, O. P.,	32–36	5–7
289	Armour Fertilizer Works, The,	Chicago, Ill.,	Blood meal,	87.0	0.20
	" " " "	" "	Meat meal,	50.0	10.0
	" " " "	" "	Meat and bone,	45.0	8.0
	" " " "	" "	Poultry bone,	25.0	5.0
283	Atlas Feed and Milling Co.,	Peoria, Ill.,	Atlas gluten meal,	35.0	12.5
310	Bagley, G. A.,	Peekskill,	G. W. Bagley & Son's mixed feed,	16.0	6.0
349	Barber, Marsh,	Buffalo,	Hermitage gluten,	22.0	7.0
371	" "	"	Corn gluten grains,	28.0	10.0
290	Barwell, J. W.,	Waukegan, Ill.,	Blatchford's calf meal,	26.0	5.0
355	" "	" "	" sugar and flaxseed,	28.25	11.25
304	Biles, J. W., Co., The,	Cincinnati, O.,	Biles' Fourex (XXXX) distiller's dried grains,	33.0	11.0

TABLE I.—MANUFACTURERS AND IMPORTERS, ETC.—(*Continued*).

License number.	Manufacturer or jobber.		Name of feed.	Guaranteed.	
	Name.	Address.		Protein.	Fat.
				Per ct.	*Per ct.*
324	Biles, J. W., Co., The,	Cincinnati, O.,	Biles' Rye (R) distiller's dried grains,	21.0	5.0
358	" " "	" "	Biles' Twoex (XX) distiller's dried grains,	30.0	8.0
370	" " "	" "	Biles' brewer's dried grains,	20–28	5–7
376	Blomo Mfg. Co.,	New York,	Blomo feed,	15.0	1.19
344	Bowker Fertilizer Co.,	" "	Bowker's beef scraps,	30.0	20.0
	" " "	" "	" animal meal,	30.0	5.0
334	Brodé, F. W., & Co.,	Memphis, Tenn.,	"Owl" cottonseed meal,	43.0	9.0
351	Brooke & Pennock,	Philadelphia, Pa.,	Sucrene dairy feed,	16.5	3.5
337	Brooks Elevator Co.,	Minneapolis, Minn.,	Royal mixed feed,	16.61	5.48
339	Buffalo Cereal Co.,	Buffalo,	Creamery feed,	20.0	5.0
	" " "	"	Poultry feed,	17.0	5.0
	" " "	"	Dairy feed,	14.0	4.0
	" " "	"	Horse feed,	12.0	4.5
	" " "	"	Corn and oat feed,	9.5	4.5
343	" " "	"	White hominy feed,	10.5	8.5
	" " "	"	Standard oat feed,	7.0	3.0
366	" " "	"	Yellow hominy feed,	10.5	8.5
291	Cassel, F. P.,	Lansdale, Pa.,	F. P. C. Chick Manna,	14.01	4.75
302	Chapin & Co.,	Buffalo,	Green diamond cottonseed meal,	43.0	9.0
	" "	"	Green oval linseed meal, O. P.,	36.0	7.0
	" "	"	Green diamond hominy feed,	11.0	8.0
364	Clark & Mercer,	Baldwinsville,	Meal and shorts,	12.05	4.15
309	Commercial Milling Co.,	Detroit, Mich.,	Dandy corn and oat chop feed,	10 81	6.02
299	Coonley, G. W.,	Albany,	Capital C. & O. feed,	9.04	3.75

298	Crow & Williams,	Ossining,	C. & W. mixed feed,	10.0	4.5
375	Curtiss, C. G., Co., The,	Buffalo,	Malt sprouts,	25.0	1.0
271	Darling & Co.,	Chicago, Ill.,	Beef scraps,	55–65	10–15
	" "	" "	" meal,	45–55	10–15
341	Dewey Bros.,	Blanchester, O.,	Corn Protegran,	36.31	8.66
332	Diamond Elevator & Milling Co.,	Minneapolis, Minn.,	"O. O." feed,	10.51	5.75
329	Diamond Mills, The,	Buffalo,	Empire State cow feed,	14.96	3.48
	" " "	"	Belmore mixed feed,	12.75	2.96
	" " "	"	Diamond C. & O. feed,	9.44	4.78
307	Ellicottville Milling Co.,	Ellicottville,	Chop feed,	8.2	4.4
315	Empire Mills,	Olean,	Empire feed,	7.63	2.97
279	Evans, C. H., & Sons,	Hudson,	Malt sprouts,	28.44	0.46
311	Everett & Treadwell,	Kingston,	C. O. & W. feed,	11.5	3.5
300	Farrington Bros.,	Syracuse,	Meal and ships,	12.0	3.5
354	Finn's, H., Sons,	"	Ground beef scraps,	40–42	18–20
378	Flint Mill Co.,	Buffalo,	Flint gluten feed,	28.5	3.0
365	Fuller, F. L., Co., The,	"	Banner corn and oat feed,	8.5	5.0
314	Glucose Sugar Refining Co., The,	Chicago, Ill.,	Buffalo gluten feed,	28.0	3.5
	" " " " "	" "	Corn oil cake meal,	25.0	10.0
322	Great Western Cereal Co., The,	" "	Great Western dairy feed,	12.3	3.2
	" " " " "	" "	Boss C. & O. feed,	9.0	4.0
	" " " " "	" "	Excelsior C. & O. feed,	9.0	4.2
	" " " " "	" "	Friends' oat feed,	8.0	3.3
	" " " " "	" "	Royal oat feed,	7.6	2.8
362	" " " " "	" "	Cream oat feed,	7.6	2.8
273	Hall, Robert E., & Co.,	Cincinnati, O.,	Hall's AAAA distiller's dried grains,	33.0	11.0
335	" " "	" "	Hall's cow feed,	20.0	7.0
342	Harding, Geo. L.,	Binghamton,	Harding's meat meal,	49.0	15.0
	" "	"	" beef scraps,	42.0	30.0
294	Hauenstein & Co.,	Buffalo,	Linseed meal, O. P.,	38.32	7.01
305	Hayt, S. T.,	Corning,	Corn and oats,	10.43	4.0

TABLE I.—MANUFACTURERS AND IMPORTERS, ETC.—(*Continued*).

License number.	Manufacturer or jobber.		Name of feed.	Guaranteed.	
	Name.	Address.		Protein.	Fat.
				Per ct.	*Per ct.*
331	Hodgman, W. S., & Co.,	Painted Post,	Corn and oat chop feed,	9.69	3.88
350	H–O Company, The,	Buffalo,	The H–O Co.'s dairy feed,	18.0	4.5
	" " "	"	" " poultry feed,	17.0	5.5
	" " "	"	" " horse feed,	12.0	4.5
	" " "	"	De-Fi corn and oat feed,	8.3	3.0
327	Hotton Bros.,	Portville,	Common feed,	8.38	4.85
363	Humphreys, Godwin & Co.,	Memphis, Tenn.,	Dixie cottonseed meal,	43.0	9.0
356	Hunter Bros.,	St. Louis, Mo.,	Hominy feed,	11.02	7.7
319	Husted Milling & Elevator Co.,	Buffalo,	Monarch chop,	10.06	4.14
382	Hygienic Food Co.,	"	Hygienic stock food,	11.56	3.62
274	Illinois Cereal Co.,	Lockport, Ill.,	Anchor corn and oat chop feed,	9.5	4.0
345	Illinois Sugar Refining Co.,	Chicago, Ill.,	Cream gluten meal,	35.5	2.4
	" " " "	" "	Pekin gluten feed,	27.0	2.5
	" " " "	" "	Pope corn bran,	13.0	3.0
317	Imperial Grain & Milling Co., The,	Toledo, O.,	No. 1 chop,	8.17	5.33
296	Kellogg, Spencer,	Buffalo,	"S. K." oil meal,	35.94	5.04
280	Kelloggs & Miller,	Amsterdam,	Pure oil meal, O. P.,	36.7	7.83
318	Kentucky Milling Co., The,	Henderson, Ky.,	Jersey mixed feed,	11.56	3.65
347	Kidder, F. L., & Co.,	Paris, Ill.,	Kidder's feed,	11.0	8.05
281	Knickerbocker Mill. & Grain Co.,	Albany,	Champion feed,	9.92	4.01
328	Lackawanna Mill & Elevator Co.,	Buffalo,	Lackawanna special horse and cattle feed,	10.93	3.48
330	Lapham & Parks,	Glens Falls,	Common feed,	7.5	3.25
333	Lowell Fertilizer Co.,	Boston, Mass.,	Swift's Lowell bone & meat meal,	50–60	8–15
359	Manitoba Mills Co.,	Cleveland, O.	Maize feed,	26.21	7.06

275	Mann Bros. Co., The,	Buffalo,	Linseed oil meal,	35.15	7.05
270	Marcus, Julius,	New York,	Ajax distiller's dried grain,	34.02	12.03
276	" "	" "	Merchant's dairy feed,	31.3–35.0	12.7–12.9
308	" "	" "	Manhattan gluten feed,	34.0	12.0
373	" "	" "	Ajax flakes,	33.56	12.49
306	McCoy & Best,	Peekskill,	Evap. bone and meat meal,	41.4	19.75
368	Meager Bros.,	Syracuse,	Meal and bran,	12.0	3.5
357	Metzger Seed & Oil Co.,	Toledo, O.,	Oil meal, O. P.,	32–36	5–7
286	Midland Linseed Co.,	Minneapolis, Minn.,	Midl'd ground linseed cake, O. P.,	32.5–37.5	5.5–8.5
352	Montezuma Mill Co.,	Montezuma, Ind.,	Hominy feed,	9.92	5.45
340	Mueller, E. P.,	Milwaukee, Wis.,	Corn distiller's grains,	30.0	12.0
	" "	" "	Malt sprouts,	26.25	1.0
	" "	" "	Calf brand,	23.85	6.15
	" "	" "	Rye distiller's grains,	22.5	8.5
	" "	" "	Molasses grains,	20.5	2.25
	" "	" "	Sugar beet feed,	10.77	1.16
361	National Starch Co.,	Chicago, Ill.,	Queen gluten feed,	27.1	3.5
295	Nester, S. K.,	Geneva,	Malt sprouts,	25.0	2.0
313	New York Glucose Co.,	New York,	Globe gluten feed,	27.0	3.38
379	Noblesville Milling Co.,	Noblesville, Ind.,	Hominy feed,	10.25–11.0	7.7–8.0
287	Oliver, Geo.,	Olean,	Chop feed,	8.58	4.86
284	Oneonta Milling Co.,	Oneonta,	Arrow corn and oat feed,	9.0	3.75
	" " "	"	Corn and oat provender,	8.75	3.5
316	Page & Drake,	Syracuse,	Empire State dairy feed,	36.22	11.76
369	Paine Bros. Co.,	Milwaukee, Wis.,	Puritan ground feed,	8.5	3.25
320	Patent Cereals Co., The,	Geneva,	Hominy chop,	11.46	9.3
297	Payne, W. H., & Son,	New York,	" "	11.49	8.0
372	*Pettit, Hugh, & Co.*,	Memphis, Tenn.,	Horseshoe cottonseed meal,	43–47	9–11
353	Pfeffer Milling Co.,	Lebanon, Ill.,	Hominy feed,	10.0	8.0
381	Pratt, Cereal Oil Co.,	Decatur, Ill.,	Germaline,	16.27	1.92
325	Romaine, DeWitt,	New York,	Boiled beef and bone,	45.0	15.0
277	Smith, A. V.,	Marcellus Falls,	Barley meal,	14.8	3.4

TABLE I.—MANUFACTURERS AND IMPORTERS, ETC.—(*Concluded*).

License number.	Manufacturer or jobber.		Name of feed.	Guaranteed.	
	Name.	Address.		Protein.	Fat.
				Per ct.	*Per ct.*
348	Stanton, H. M.,	Schenectady,	Ground scraps,	50.0	9.0
326	Staples, A. S.,	Rondout,	Arcade Mills mixed feed,	10.45	5.86
278	Streeter, L. L., & Sons,	Johnstown,	Common feed,	8.78	5.23
367	Strong, Lefferts Co.,	New York,	Lenox stock food,	9.88	3.27
321	Suffern, Hunt & Co.,	Decatur, Ill.,	Hominy feed,	11.02	7.70
338	Terwilliger, C. A.,	Niagara Falls,	Niagara chop,	10.42	4.83
282	Toledo Elevator Co., The,	Toledo, O.,	Regular hominy.	12.6	8.57
	" " "	" "	Star feed,	11.4	7.31
312	Union Linseed Co.,	Troy,	"Cow" oil meal,	22.09	6.32
303	U. S. Frumentum Co.,	Detroit, Mich.,	Frumentum hominy feed,	10.31	7.98
323	Victor Mills,	Springville,	Golden chop,	9.17	5.84
336	Wallace, L. R.,	Middletown,	"Mapes" Balanced ration for poultry,	14.0	4.5
301	Waller, A., & Co.,	Henderson, Ky.,	Blue grass mixed feed,	12.59	3.19
380	Warner Sugar Refining Co.,	Waukegan, Ill.,	Warner gluten feed,	28.00	3.5
377	Wilson & Wolven,	Kingston,	Nebraska chop,	12.40	5.62

The list of licensed brands may be classified as follows:

Proprietary or mixed feed	78	brands	Sugar beet refuse	2	brands
Meat and bone meal	15	"	Brewer's grains	1	brand
Distiller's grains	14	"	Corn bran	1	"
Hominy feed or chop	13	"	Corn oil cake	1	"
Linseed meal	9	"	Gluten meal	1	"
Cottonseed-meal	5	"	Molasses grains	1	"
Gluten feed	6	"			
Malt sprouts	4	"	Total	151	brands

ANALYSES OF SAMPLES COLLECTED BY INSPECTORS.

The following table (II) shows the partial analyses of samples of feeding stuffs collected by inspectors in various parts of the State from Oct. 9, 1902, to Feb. 6, 1903.

The percentages of protein and fat guaranteed are given for comparison with the amounts actually present. In order to determine the true value of feeds we must look into the carbohydrate portion, and the presence of coffee hulls, oat hulls, corn-cobs, or other inferior ingredients is usually shown by an abnormal amount of crude fiber. Therefore, in most of the samples the percentage of crude fiber was determined. The table also includes the retail prices per ton.

TABLE II.—ANALYSES OF FEEDING

Collection No.	Name and address of manufacturer or jobber.	Sampled at
633	American Cotton Oil Co., New York,	Waterville, Hubbard & King,
653	" " " " " "	Delhi, Dean & Bramley,
693	" " " " " "	Richmondville, M. W. Harroway,
862	" " " " " "	Hornellsville, Stephen Holland,
666	Biggs, R. W., & Co., Memphis, Tenn.,	Unadilla, S. H. Chapin,
643	Brodé, F. W., & Co., " "	Walton, J. Wright,
957	" " " " "	Jamestown, F. A. Smiley & Co.,
1040	" " " " "	Buffalo, Buffalo Cereal Co.,
761	Chapin & Co., Buffalo,	Attica, J. P. Frey,
813	" " "	Olean, Olean Mills,
981	Falls, J. G., & Co., Memphis, Tenn.,	Lockport, J. Young,
582	Humphreys, Godwin & Co., Memphis, Tenn.,	Utica, G. W. Head & Co.,
726	Pettit, Hugh, & Co.,	Cortland, G. W. Webster & Son,
529	Travis, W. S., New York,	New York, Clark & Allen,
547	Williams, E. B., & Co., Memphis, Tenn.,	Amsterdam, W. N. Carpenter,
553	Biles, The J. W., Co., Cincinnati, O.,	Syracuse, Henry Frier,
700	" " " " "	Canastota, F. T. Benjamin,
714	" " " " "	New Woodstock, C. H. Boyd,
753	" " " " "	Batavia, C. H. & H. N. Douglass,
779	" " " " "	Alexander, W. E. Moulton & Co.,
974	" " " " "	Falconer, Falconer Mill Co.,
916	Chapin & Co., Buffalo,	Angola, Bundy Milling Co.,
586	Hottelet & Co., Milwaukee, Wis.,	Utica, McLoughlin Bros.,
613	American Spirits Mfg. Co., Peoria, Ill.,	Binghamton, Benj. Baker,
835	" " " " " "	Wellsville, J. W. Gollman & Co.,
889	" " " " " "	Cattaraugus, A. T. Bensen,
961	" " " " " "	Jamestown, F. A. Smiley & Co.,
618	Meurer, Deutsch & Sickert Co., Milwaukee, W.	Binghamton, Em. G'n & El. Co.,
674	Dewey Bros., Blanchester, O.,	Oneonta, Morris Bros.,
730	Fuller, Page Co., Syracuse,	De Ruyter, S. D. Thompson,
712	Merchants Distilling Co., Terre Haute, Ind.,	New Woodstock, E. E. Hatch & Co.,
799	" " " " " "	Bliss, Bliss Milling Co.,
826	" " " " " "	Cuba, S. R. Lawn,
634	Biles, The J. W., Co., Cincinnati, O.,	Waterville, Hubbard & King,
619	Mueller, E. P., Milwaukee, Wis.,	Binghamton, Em. G'n & Elv. Co.,
630	Glucose Sugar Refining Co., Chicago, Ill.,	Sherburne, Finks & Wilcox,
654	" " " " " "	Walton, A. A. Haverly,
926	Milwaukee Linseed Oil W'ks, Milwaukee, W.	Dunkirk, Wm. Ruechert,
530	Midland Linseed Oil Co., Minneapolis, Minn.,	New York, Clark & Allen,
713	" " " " " "	New Woodstock, E. E. Hatch & Co.,
780	" " " " " "	Alexander, W. E. Moulton & Co.,

STUFFS COLLECTED BY INSPECTORS.

Collection No.	Name of feed.	Protein.		Fat.		Crude fiber found.	Price per ton.
		Found	Guaranteed.	Found.	Guaranteed.		
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
633	Cottonseed meal, prime,	42.6	43.0	10.2	9.0		$27.00
653	“ “ “	40.7	43.0	11.7	9.0		29.00
693	“ “ “	46.4	43.0	9.1	9.0		28.00
862	“ “ “	46.1	43.0	7.9	9.0		28.00
666	† “ “ Canary,	44.7	48.0	8.7	9.0		28.00
643	“ “ Owl,	41.5	43.0	8.9	9.0		29.00
957	“ “ “	40.8	43.0	9.7	9.0		30.00
1040	“ “ “	41.3	43.0	9.4	9.0		27.00
761	“ “ Green diamond,	42.8	43.0	7.2	9.0		33.00
813	“ “ “ “	44.4	43.0	7.7	9.0		31.00
981	† “ “ Southern beauty,	42.8	43.0	11.2	9.0		31.00
582	“ “ Dixie,	43.9	43.0	8.0	9.0		27.00
726	“ “ Horseshoe,	43.4	43.0	9.9	9.0		27.00
529	“ “ prime,	42.9	43.0	9.4	9.0		32.00
547	† “ “ Daisy,	43.3	43.0	8.5	9.0		26.00
553	Distiller's dried grains, XXXX,	36.5	33.0	11.6	11.0		25.00
700	“ “ “ “	36.0	33.0	11.4	11.0		26.00
714	“ “ “ “	31.6	33.0	10.3	11.0		24.50
753	“ “ “ “	36.3	33.0	11.7	11.0		23.00
779	“ “ “ “	34.6	33.0	11.2	11.0		25.00
974	“ “ “ “	34.8	33.0	11.1	11.0		25.00
916	“ “ “ Ajax,	34.6	34.02	13.3	12.03		24.00
586	“ “ “ “	36.9		11.5			25.00
613	Gluten feed, Manhattan,	41.0	31.8-36.2	13.2	10.8-11.8		24.00
835	“ “ “	37.1	31.8-36.2	11.7	10.8-11.8		23.50
889	“ “ “	32.1	31.8-36.2	10.5	10.8-11.8		25.00
961	“ “ “	37.3	31.8-36.2	11.0	10.8-11.8		25.00
618	“ “ Lake Side,	35.3	36.0	12.2	11.0		19.50
674	Protegran-Ideal dairy feed,	35.8	36.31	10.8	8.66		25.00
730	Mohawk dairy feed,	36.6	35.6	13.7	12.4		24.00
712	Merchants' dairy feed,	35.8	31.3-35.0	12.9	12.7-12.9		25.00
799	“ “ “	33.1	31.3-35.0	13.3	12.7-12.9		24.50
826	“ “ “	36.1	31.3-35.0	13.3	12.7-12.9		24.00
634	Brewer's dried grains,	34.8	20.0-28.0	7.8	5.0 - 7.0	11.9	19.00
619	† “ “ “	28.9	24.86	6.8	5.69	14.1	18.00
630	Germ oil meal,	21.6	25.0	8.7	10.0		
654	“ “ “	23.6	25.0	8.2	10.0		24.00
926	† Linseed cake, ground,	35.1	34.0	9.9	5.0		34.00
530	“ “ “ O. P.,	31.2	32.5-37.5	9.0	5.5 - 8.5		30.00
713	“ “ “ “	32.6	32.5-37.5	9.6	5.5 - 8.5		27.00
780	“ “ “ “	30.4	32.5-37.5	8.1	5.5 - 8.5		35.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
807	Midland Linseed Oil Co., Minneapolis, Minn.,	Olean, Empire Mills,
898	" " " " " "	Hamburgh, G. W. Eddy,
526	American Linseed Co., New York,	New York, W. H. Payne & Son,
573	" " " " "	Syracuse, J. C. Surbeck,
616	" " " " "	Binghamton, G. Q. Moon & Co.,
648	" " " " "	Delhi, Cooperative store,
682	" " " " "	Oneonta, Oneonta Milling Co.,
746	" " " " "	Batavia, C. F. Ballard,
787	" " " " "	Warsaw, D. E. Keeney & Son,
1021	" " " " "	Buffalo, Diamond Mills,
1039	" " " " "	Buffalo, Buffalo Cereal Co.,
1045	" " " " "	Buffalo, American Linseed Co.,
940	Crouch Bros. Co., Erie, Pa.,	Westfield, J. H. Waterman,
785	Hauenstein & Co., Buffalo,	Warsaw, Montgomery Bros.,
924	" " "	Dunkirk, J. W. O'Brien & Co.,
797	Kellogg, Spencer, Buffalo,	Perry, T. H. Donnelly,
1044	" " "	Buffalo, Spencer Kellogg,
702	Kelloggs & Miller, Amsterdam,	Camden, Penfield & Stone,
741	Mann Bros. Co., Buffalo,	Batavia, E. J. Salway,
755	" " "	Batavia, C. H. & H. N. Douglass,
849	Metzger Seed & Oil Co., Toledo, O.,	Wellsville, J. B. Tompkins & Co.,
883	" " " " "	Little Valley, G. W. Griffith,
675	Union Linseed Co., Troy,	Oneonta, Oneonta Milling Co.,
644	Glucose Sugar Refining Co., Chicago, Ill.,	Walton, John Wright,
935	Pope, Chas., Glucose Co., Chicago, Ill.,	Westfield, H. V. Herrick,
770	American Glucose Co., Chicago, Ill.,	Attica, Attica Mills,
556	Glucose Sugar Refining Co., Chicago, Ill.,	Syracuse, L. L. Patterson & Son,
567	" " " " " "	Syracuse, Meager Bros.,
629	" " " " " "	Sherburne, Finks & Wilcox,
656	" " " " " "	Walton, A. A. Haverly,
692	" " " " " "	Richmondville, M. W. Harroway,
812	" " " " " "	Olean, Olean Mills,
816	" " " " " "	Olean, Acme Milling Co.,
894	" " " " " "	Hamburg, John Schoefflin,
911	" " " " " "	East Aurora, Griggs & Ball,
1018	" " " " " "	Buffalo, Diamond Mills,
910	Heinhold, J. G., Buffalo,	Lancaster, P. P. Mook,
984	Illinois Sugar Refining Co., Chicago, Ill.,	Lockport, J. O. Rignal,
993	" " " " "	Buffalo, Husted M'l'g & El'v Co.,
647	National Starch Co., Chicago, Ill.,	Walton, John Wright,
1066	" " " "	Buffalo, National Starch Co.,
539	New York Glucose Co., New York,	Peekskill, G. A. Bagley & Son,
691	" " " "	Richmondville, M. W. Harroway,
865	" " " "	Hornellsville, S. Holland,
973	" " " "	Falconer, Falconer Milling Co.,
642	Dean, C. R., Owego,	Sidney, Sidney Flour & F'd Co.,
680	Oneonta Milling Co., Oneonta,	Oneonta, Oneonta Milling Co.,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found	Fat. Guaranteed.	Crude fiber found	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
807	Linseed oil meal, O. P.,	30.3	32.5–37.5	9.1	5.5–8.5		$32.00
898	" " "	32.3	32.5–37.5	8.9	5.5–8.5		35.00
526	" " "	31.4	32.0–36.0	6.9	5.0–7.0		
573	" " "	35.3	32.0–36.0	7.0	5.0–7.0		30.00
616	" " "	34.6	32.0–36.0	6.5	5.0–7.0		28.00
648	† " " fine ground,	39.2	37.5–40.0	2.2	1.0–3.0		30.00
682	† " " "	36.9	37.5–40.0	2.1	1.0–3.0		29.00
746	" " O. P.,	35.3	32.0–36.0	7.3	5.0–7.0		35.00
787	" " "	33.1	32.0–36.0	6.9	5.0–7.0		35.00
1021	" " "	33.3	32.0–36.0	7.3	5.0–7.0		27.00
1039	" " "	34.1	32.0–36.0	7.2	5.0–7.0		26.50
1045	" " "	33.0	32.0–36.0	7.7	5.0–7.0		26.50
940	† " " "	29.9		7.3			35.00
785	" " "	33.5	37.82	7.3	7.54		40.00
924	" " "	34.0	37.82	7.6	7.54		32.00
797	" " "	34.4	35.94	10.0	5.04		30.00
1044	" " "	33.3	35.94	13.4	5.04		27.00
702	" " "	34.8	36.7	8.2	7.83		38.00
741	" " "	38.3	35.15	7.7	7.05		40.00
755	" " "	35.8	35.15	7.0	7.05		34.00
849	" " "	31.8	32.0–36.0	6.7	5.0–7.0		30.00
883	" " "	31.4	32.0–36.0	7.3	5.0–7.0		35.00
675	" " Cow brand,	33.6	22.09	6.6	6.32		26.00
644	†‡ Gluten meal, Chicago,	33.9	38.0	3.0	4.0		28.00
935	" " Cream,	41.2	38.0–40.0	0.55	2.5–3.0		32.00
770	† Gluten feed,	25.9		4.0			24.00
556	" " Buffalo,	27.6	28.0	4.5	4.0		25.00
567	" " "	27.4	28.0	2.5	4.0		25.00
629	" " "	24.8	28.0	2.8	4.0		25.00
656	" " "	27.9	28.0	2.7	4.0		24.00
692	" " "	27.6	28.0	2.5	4.0		26.00
812	" " "	27.6	28.0	2.8	4.0		27.00
816	" " "	27.9	28.0	2.6	4.0		24.50
894	" " "	26.2	28.0	4.2	4.0		22.50
911	" " "	28.2	28.0	2.8	4.0		26.00
1018	" " "	24.6	28.0	2.9	4.0		27.50
910	" " "	25.2		3.3			24.00
984	" " Pekin,	25.8	27.7	3.8	3.5		26.00
993	" " "	24.6	27.7	3.4	3.5		25.00
647	" " Queen,	23.4	27.1	1.8	3.5		26.00
1066	" " "	22.4	27.1	2.5	3.5		
539	" " Globe,	24.7	27.0	3.0	3.38		26.00
691	" " "	26.8	27.0	2.5	3.38		26.00
865	" " "	25.4	27.0	3.7	3.38		24.00
973	" " "	27.8	27.0	2.9	3.38		25.00
642	† " " Special,	14.6	13.5	2.8	3.7	11.2	20.00
680	† " " "	12.4	14.0	3.4	4.0		20.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
1058	Curtis, C. G., Co., Buffalo,	Buffalo, C. G. Curtis Co.,
1025	Dole, F. A., Buffalo,	Buffalo, F. A. Dole,
907	Heinhold, J. G., Buffalo,	Lancaster, P. P. Mook,
1046	Kam Malting Co., Buffalo,	Buffalo, Henry & Missert,
1061	" " " "	Buffalo, Kam Malting Co.,
1060	Voltz, J. S., & Co., Buffalo,	Buffalo, J. S. Voltz & Co.,
905	Wheinhold, Geo., Buffalo,	Lancaster, Adolf Bros.,
824	Acme Food Co., Chicago, Ill.,	Olean, Olean Supply Co.,
601	Barwell, J. W., Waukegan, Ill.,	Homer, W. H. Darby,
635	" " " "	Waterville, Hubbard & King,
670	" " " "	Otego, Oneonta Milling Co.,
740	" " " "	Batavia, E. J. Salway,
872	" " " "	Salamanca, C. F. Buckmaster,
602	" " " "	Homer, W. H. Darby,
766	International Food Co., Minneapolis, Minn.,	Attica, J. P. Frey,
623	American Cereal Co., Chicago, Ill.,	Oxford, French & Mead,
708	" " " " "	Oneida, E. J. Buyea,
983	" " " " "	Lockport, W. E. & H. K. Wicker
1029	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
591	Great Western Cereal Co., Chicago, Ill.,	Phoenix, A. C. Parker,
754	" " " " " "	Batavia, C. H. & H. N. Douglass
971	" " " " " "	Jamestown, B. R. Welton,
901	H-O Company, Buffalo,	Hamburg, A. N. Conger,
923	" " "	Dunkirk, J. W. O'Brien & Co.,
1002	" " "	Buffalo, H-O Co.,
1030	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
551	" " " "	Syracuse, Jacob Amos,
1026	" " " "	Buffalo, Buffalo Cereal Co.,
583	H-O Company, Buffalo,	Utica, Ogden & Clark,
660	" " "	Oneonta, Morris Bros.,
739	" " "	Batavia, E. J. Salway,
900	" " "	Hamburg, A. N. Conger,
999	" " "	Buffalo, H-O Co.,
665	Oneonta Milling Co., Oneonta,	Unadilla, S. H. Chapin,
749	Douglass, C. H. & H. N., Batavia,	Batavia, C. H. & H. N. Douglass
866	Cameron Mills, Cameron Mills,	Hornellsville, S. Holland,
952	Chambers MacKay Co., Minneapolis, Minn.,	Sherman, Wilk'n, Gaddis & Co.,
936	Wellman, H. & Co., Minneapolis, Minn.,	Westfield, H. V. Herrick,
994	Woodworth, E. S., & Co., Minneapolis, Minn.,	Buffalo, Husted Mill. & El. Co.
1054	Imperial Milling Co., Duluth, Minn.,	Buffalo, A. A. Engle,
930	Ansted & Burke, Springfield, O.,	Fredonia, Colburn Bros.,
941	Bacon, David, Westfield,	Westfield, J. H. Waterman,
801	Banner Milling Co., Buffalo,	Bliss, Bliss Milling Co.,
954	Chapin & Co., St. Louis, Mo.,	Sherman, Wilk'n, Gaddis & Co.,
950	Commercial Milling Co., Cleveland, O.,	Mayville, Chau. Lake Mills.,
870	Combs, W. A., Co., Coldwater, Mich.,	Salamanca, C. F. Buckmaster,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
1058	Malt sprouts,	28.4	25.0	2.0	1.0		$14.00
1025	† " "	24.9		1.6			14.00
907	" "	23.1		1.4			16.00
1046	† " "	27.9		1.4			16.00
1061	† " "	27.9		1.6			12.00
1060	† " "	28.6		1.8			15.00
905	† " "	27.6		1.7			15.00
824	§ Acme stock food,	19.8		6.5			120.00
601	Blatchford's calf meal,	25.0	26.0	4.6	5.0		70.00
635	" "	25.0	26.0	4.8	5.0		70.00
670	" "	25.0	26.0	5.1	5.0		70.00
740	" "	25.4	26.0	5.0	5.0		80.00
872	Blatchford's sugar and flaxseed,	27.6	28.25	10.0	11.25		80.00
602	† Shepard's lamb food,	23.9		4.7			70.00
766	§ International stock food,	12.1		3.0			300.00
623	Dairy feed, Quaker,	14.3	14.0	3.1	3.5	15.9	21.00
708	" " "	15.1	14.0	3.9	3.5	16.8	18.00
983	" " "	14.1	14.0	3.6	3.5	16.4	20.00
1029	" " "	14.4	14.0	4.1	4.0	10.3	22.00
591	" " Daisy,	9.4	12.25	2.1	3.2	21.7	18.00
754	" " "	7.8	12.25	2.9	3.2	23.2	15.00
971	" " "	7.0	12.25	2.4	3.2	26.9	20.00
901	" " H-O,	17.0	18.0	4.4	4.5	13.3	26.00
923	" " "	18.2	18.0	3.9	4.5	13.2	26.00
1002	" " "	18.4	18.0	4.2	4.5	14.3	26.00
1030	Creamery feed,	23.3	20.0	5.0	5.5	11.0	24.00
551	Horse feed,	12.6	12.0	4.9	4.5	9.7	26.00
1026	" "	12.1	12.0	4.4	4.5	10.2	24.00
583	" " H-O,	12.1	12.0	4.3	4.5	9.6	29.00
660	" " "	13.8	12.0	4.7	4.5	9.2	27.00
739	" " "	12.5	12.0	4.7	4.5	9.5	28.00
900	" " "	12.3	12.0	4.5	4.5	9.4	26.00
999	" " "	11.1	12.0	4.3	4.5	9.0	26.50
665	† " " Monarch,	14.9	13.0	5.3	5.75	6.2	26.00
749	† Horse and cattle feed, Boss,	7.7	6.25	2.6	3.65	15.6	17.50
866	Middlings, buckwheat,	24.3		*			20.00
952	Flour, Red Dog,	20.5		6.0			23.00
936	" " "	19.8		5.3			26.00
994	" " "	19.8		4.9			23.00
1054	" " "	18.0		3.8			22.00
930	Middlings, wheat,	16.6		4.2			24.00
941	" "	18.6		6.1			25.00
801	" "	17.0		4.1			25.00
954	" "	16.4		3.6			21.00
950	" "	17.7		4.7			24.00
870	" "	16.3		3.6			24.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
776	Ewart & Lake, Groveland Station.	Attica, B. F. Bennett,
864	Freeman Milling Co., Duluth, Minn.,	Hornellsville, S. Holland,
966	Goshen Milling Co., Goshen, Ind.,	Jamestown, Jackson Bros.,
1073	Heinhold, J. G., Buffalo,	Jamestown, C. P. Carlson,
876	Grandin, D. H., Jamestown,	Salamanca, Henry Neff,
748	Humboldt Milling Co., Minneapolis, Minn.,	Batavia, E. F. Ballard,
803	Hydraulic Mill Co., Buffalo,	Bliss, E. E. Buck,
967	Listman Mill Co., LaCrosse, Wis.,	Jamestown, Jackson Bros.,
818	Northwestern Mill & Elev. Co., Toledo, O.,	Olean, Acme Milling Co.,
977	Poland Roller Mills, Kennedy,	Kennedy, Poland Roller Mills,
838	Rankin, M. G., Milwaukee, Wis.,	Wellsville, Scoville Brown & Co.
909	Rex Mill Co., Kansas City, Mo.,	Lancaster, P. P. Mook,
789	Roberts Bros., Warsaw,	Warsaw, D. E. Keeney & Son,
845	Sheffield, King Co., Faribault, Minn.,	Wellsville, J. B. Tompk's & Son
888	Stocks Milling Co., Buffalo,	Cattaraugus, A. T. Benson,
737	Thompson Milling Co., Lockport,	Batavia, E. J. Salway,
884	Toledo Grain & Milling Co., Toledo, O.,	Little Valley, W. S. Mattoon,
885	" " " " " "	" " "
771	Urban Mill Co., Buffalo,	Attica, Attica Mills,
896	" " "	Hamburg, J. Schoefflin,
796	Washburn, Crosby & Co., Minneapolis, Minn.,	Perry, J. J. Martin,
880	" " " " "	Salamanca, E. J. Sowl,
757	West Avenue Mill Co., Attica,	Attica, J. P. Frey,
811	Woodworth, E. S., & Co., Minneapolis, Minn.,	Olean, Olean Mills,
848	" " " "	Wellsville, J. B. Tompk's & Son
1055	Thornton & Chester, Buffalo,	Buffalo, C. E. Pollard,
1019	Pillsbury & Co., Minneapolis, Minn.,	Buffalo, Diamond Mills,
1051	Urban Mills, Buffalo,	Buffalo, Urban Mills,
743	Colquhoun & Waldruff, Batavia,	Batavia, Colquhoun & Waldruff
1022	Diamon Mills, Buffalo,	Buffalo, Diamond Mills,
887	Hunter, O. L., & Co., Chicago, Ill.,	Cattaraugus, A. T. Benson,
1042	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
833	Stafford Mill & Elevator Co., Stafford, Kas.,	Wellsville, J. W. Gollman & Co.
853	Tanner, A., Little Falls, Minn.,	Belmont, Hood & Bradley,
919	Bundy Milling Co., Angola,	Angola, Bundy Milling Co.,
685	Acme Milling Co., Indianapolis, Ind.	Middleburg, W. C. West,
720	Ankeny, W. S., & Co., Minneapolis, Minn.,	Marathon, Marathon Roll. Mills
934	Bennett, Craft & Kauffman Milling Co., St. Louis, Mo.,	Fredonia, O. M. & J. R. Hall,
562	Belmore Mills, Belmore, O.,	Syracuse, F. P. Williamson,
1015	" " " "	Buffalo, Diamond Mills,
631	Blish Milling Co., Seymour, Ind.,	Sherburne, S. W. Lobbell,
723	" " " " "	Marathon, J. H. Seeber & Son,
949	" " " " "	Mayville, Chau. Lake Mills,
861	Chapin & Co., Buffalo,	Hornellsville, S. Holland,
918	" " "	Angola, Bundy Milling Co.,
953	" " "	Sherman, Wilk'n, Gaddis & Co.,
645	Fertig, H. G., & Co., Minneapolis, Minn.,	Walton, John Wright,
943	Hunter Bros., St. Louis, Mo.,	Brocton, V. Mathews,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
776	Middlings, wheat,	16.1		4.1			$24.50
864	" "	15.8		5.2			24.00
966	" "	15.9		4.1			24.00
1073	" "	14.2		2.9		5.8	20.50
876	" "	17.4		3.6			21.00
748	" "	18.3		5.4		8.5	23.00
803	" "	15.9		4.3			24.00
967	" "	20.0		5.6			24.00
818	" "	18.1		3.9			21.50
977	" "	16.8		5.0			21.00
838	" "	20.8		5.1		4.5	22.00
909	" "	18.9		4.5			22.00
789	" "	15.5		4.3			24.00
845	" flour,	19.5		5.7		7.0	25.00
888	" wheat,	17.1		4.5		5.4	20.00
737	" "	16.3		4.5			24.00
884	" " No. 2,	15.1		6.1		5.8	23.00
885	" " white,	15.1		5.1		2.9	25.00
771	" "	16.9		4.9			20.00
896	" "	16.8		4.9			19.00
796	" "	16.1		4.8			24.00
880	" "	17.8		4.9		6.4	22.00
757	" "	17.9		5.9			22.00
811	" "	18.9		5.1			24.00
848	" Snow's cream,	19.4		5.0			25.00
1055	" blended,	16.4		4.8			19.00
1019	" spring wheat,	18.3		5.3			20.00
1051	" " "	16.1		4.3			19.00
743	" winter wheat,	15.8		4.9			23.00
1022	" " "	15.1		4.8			19.00
887	" " "	19.0		5.4			20.00
1042	" oat,	17.4		7.8		2.4	20.00
833	Shorts,	19.2		5.0			23.50
853	"	15.3		5.2		5.6	24.00
919	† Middlings and hominy feed,	13.9		4.7		3.9	23.00
685	Mixed feed, Acme,	17.4		4.4		7.4	23.00
720	" "	18.8		4.6		6.6	22.00
934	" " bran and middlings,	16.8	12.75	4.3	2.96	6.7	21.00
562	" "	12.8	12.75	3.7	2.96	13.9	20.00
1015	" "	11.7		2.7		15.5	28.30
631	" "	17.3		4.5		8.1	21.00
723	" "	17.5		4.5		7.6	21.00
949	" "	17.3		4.5		7.3	22.00
861	" " King,	17.8		4.5		6.5	22.00
918	" " spring,	16.4		4.8		8.5	20.00
953	" " Erie winter,	17.9		4.3		7.7	20.00
645	" " Monogram,	17.6		5.2		7.1	22.00
943	" "	18.9		3.9		7.5	20.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
996	Hunter Bros., St. Louis, Mo.,	Buffalo, Husted M. & Elev. Co.
689	" " "	Richm'dville, M. W. Harroway,
651	" " "	Delhi, Coöperative Store,
690	" " "	Richm'dville, M. W. Harroway,
628	Imperial Mills, Duluth, Minn.,	Oxford, Fletcher & Corbin,
672	Kehler Bros., St. Louis, Mo.,	Otego, P. R. Jennings,
696	" " "	Worcester, P. H. Platts,
886	Kentucky Milling Co., Henderson, Ky.,	Cattaraugus, A. T. Benson,
679	Lawrenceburg, Roller Mill. Co., Law'b'g, Ind.,	Oneonta, Oneonta Milling Co.,
705	" " " "	Rome, Hughes & Wilkenson,
541	Listman, Wm., Milling Co., Superior, Wis.,	Kingston, Wilson & Wolven,
932	Moore, R. P., Princeton, Ind.,	Fredonia, O. M. & J. R. Hall,
938	" " "	Westfield, H. V. Herrick,
694	Morris Bros., Oneonta,	Richmondville, Fox Bros.,
640	Noblesville Milling Co., Noblesville, Ind.,	Sidney, A. J. Ives,
699	" " " "	Richfield Springs, W. B. Ward,
721	Plant, G. P., & Co., St. Louis, Mo.,	Marathon, Marathon Roll. Mills
715	Rex Milling Co., Kansas City, Mo.,	Cazenovia, L. M. Woodworth,
834	" " " "	Wellsville, J. W. Gollman & Co.
908	" " " "	Lancaster, P. P. Mook,
632	" " " "	Waterville, Hubbard & King,
671	Russell, Henry, Albany,	Otego, P. R. Jennings,
729	Stott, David, Detroit, Mich.,	De Ruyter, C. S. Church,
592	Waller, A., & Co., Henderson, Ky.,	Phoenix, A. C. Parker,
678	" " "	Oneonta, Oneonta Milling Co.,
707	" " "	Rome, G. Oster & Son,
543	Washburn-Pillsbury Co., Minneapolis, Minn.,	Saugerties, F. G. Phelps,
687	" " " "	Schoharie, E. L. Auchampaugh,
756	West Avenue Mill Co., Attica,	Attica, J. P. Frey,
650	Woodworth, E. S., & Co., Minneapolis, Minn.,	Delhi, Coöperative Store,
710	Evans, Geo. T., Indianapolis, Ind.,	N. Woodst'k, E. E. Hatch & Co.
725	" " " "	Marathon, J. H. Seeber & Son,
852	" " " "	Belmont, Hood & Bradley,
1067	Hunter Bros., St. Louis, Mo.,	Buffalo, Cutter & Bailey,
606	American Cereal Co., Chicago, Ill.,	Cortland, C. M. Jennings,
624	" " " "	Oxford, French & Mead,
727	" " " "	De Ruyter, J. W. West,
839	" " " "	Wellsville, C. B. Hyslip,
781	Moulton, W. E., & Co., Alexander,	Alexander, W. E. Moulton & Co.,
655	Star & Crescent Milling Co., Chicago, Ill.,	Walton, A. A. Haverly,
706	Thornton & Chester, Buffalo,	Rome, Hughes & Wilkenson,
831	" " "	Wellsville, Wethersby & Keller,
1010	" " "	Buffalo, Thornton & Chester,
734	Albion Milling Co., Albion, Mich.,	Batavia, Rob't Adams,
744	Colquhoun & Waldruff, Batavia,	Batavia, Colquhoun & Waldruff,
962	Combs, W. A., & Co., Coldwater, Mich.,	Jamestown, F. A. Smiley & Co.,
969	" " " "	Jamestown, Hayward & Co.,
775	Ewart & Lake, Groveland Station,	Attica, B. F. Bennett,
960	Firth Roller Mills, Firth, Neb.,	Jamestown, F. A. Smiley & Co.,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
996	Mixed feed, bran and middlings,	17.0		4.4		7.7	$21.25
689	" " L.,	19.1		4.2		7.2	20.00
651	" " Sunshine,	18.3		4.4		7.6	20.00
690	" " "	18.0		4.2		6.7	20.00
628	" " Boston,	17.1		4.8		8.5	20.00
672	" "	17.3		4.4		7.0	20.00
696	" "	18.2		4.2		7.2	20.00
886	" " Jersey,	12.9	11.56	3.0	3.65	14.3	18.00
679	" " Snowflake,	17.1		4.3		7.2	20.50
705	" " "	17.5		4.2		6.8	21.00
541	" " Hiawatha,	18.3		4.2		6.6	24.00
932	" " King, bran and mid's,	18.2		4.5		6.9	21.00
938	" " " "	18.0		4.4		7.2	20.00
694	" " Delaware,	17.3		4.3		6.8	21.00
640	" " N. M. Co.'s,	16.8		4.5		7.0	19.00
699	" " "	17.4		4.5		7.1	21.00
721	" "	16.8		4.5		7.2	22.00
715	" "	18.9		4.4		7.6	20.00
834	" "	18.1		4.4		7.3	20.00
908	" "	18.7		4.5		7.6	20.00
632	" "	17.0		4.9		7.2	21.00
671	" "	17.5		5.3		7.8	22.00
729	" " Stott's,	17.0		4.8		8.4	21.00
592	" " Blue Grass,	11.4	12.59	3.1	3.19	14.5	20.00
678	" " "	12.8	12.59	3.3	3.19	13.3	19.00
707	" " "	11.1	12.59	2.3	3.19	16.6	19.00
543	" " Pillsbury's Fancy,	18.4		5.0		5.8	26.00
687	" " " "	18.6		5.4		7.6	25.00
756	" " bran and middlings,	17.3		5.1		8.3	18.00
650	" " Snow's,	17.1		5.1		8.4	22.00
710	Mixed mill feed, Hoosier,	17.7		4.4		7.3	21.00
725	" " "	17.7		4.3		7.2	21.00
852	" " "	17.3		4.3		7.0	23.00
1067	" "	17.1		4.6		7.4	20.00
606	Wheat feed, Buckeye,	16.6	17.75	4.3	4.7	7.0	23.00
624	" " "	16.9	17.75	4.3	4.7	6.7	22.00
727	" " "	17.8	17.75	4.8	4.7	7.5	23.00
839	" " "	16.6	17.75	4.4	4.7	7.2	20.00
781	" " ground,	10.7		2.1		1.8	25.00
655	" " Star & Crescent gr'nd,	17.7		4.5		7.4	21.00
706	" " mixed,	17.0		5.4		8.7	20.00
831	" " "	17.8		5.3		8.6	20.00
1010	" " "	15.4		5.1		8.2	19.25
734	Bran, winter wheat,	16.8		4.0		8.4	20.00
744	"	14.8		3.6		9.1	20.00
962	"	16.8		3.9		8.1	20.00
969	"	16.8		4.7		8.5	20.00
775	" (mostly middlings),	14.8		3.2		2.3	20.00
960	" winter wheat, choice,	16.1		2.3		10.3	20.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
827	Fuller, Page & Co., Syracuse,	Cuba, S. R. Lawn,
956	Goshen Milling Co., Goshen, Ind.,	Sherman, Wilk'n, Gaddis & Co.,
1070	Grandin, D. H., Jamestown,	Jamestown, Alonzo Martin,
1072	" " "	Jamestown, C. P. Carlson,
892	Harter, Isaac, Co., Toledo, O.,	Cattaraugus, True & Young,
877	Heinhold, J. G., Buffalo,	Salamanca, Henry Neff,
772	Houk, P., Sons, Tonawanda,	Attica, Attica Mills,
747	Humbolt Milling Co., Minneapolis, Minn.,	Batavia, E. F. Ballard,
893	Hunter Bros., St. Louis, Mo.,	Cattaraugus, True & Young,
804	Hydraulic Mill Co., Buffalo,	Bliss, E. E. Buck,
735	Listman Mill Co., LaCrosse, Wis.,	Batavia, Robert Adams,
933	Moore, R. P., Princeton, Ind.,	Fredonia, O. M. & J. R. Hall,
1020	National Milling Co., Toledo, O.,	Buffalo, Diamond Mills,
751	Northwestern Consolidated Milling Co., Minneapolis, Minn.,	Batavia, C. H. & H. N. Douglass
792	Northwestern Consolidated Milling Co., Minneapolis, Minn.,	Perry, Geo. Tomlinson & Son,
917	Northwestern Consolidated Milling Co., Minneapolis, Minn.,	Angola, Bundy Milling Co.,
1024	Pillsbury Co., Minneapolis, Minn.,	Buffalo, Diamond Mills,
788	Robberts Bros., Warsaw,	Warsaw, D. E. Keeney & Son,
830	Thornton & Chester, Buffalo,	Wellsville, Wetherby & Keller,
1056	" " "	Buffalo, C. E. Pollard,
736	Thompson Milling Co., Lockport,	Batavia, E. J. Solway,
758	Urban Mills, Buffalo,	Attica, J. P. Frey,
762	" " "	" " "
1050	" " "	Buffalo, Urban Mills,
819	Voight Milling Co., Grand Rapids, Mich.,	Olean, Acme Milling Co.,
752	Washburn, Crosby Co., Minneapolis, Minn.,	Batavia, C. H. & H. N. Douglass
1041	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
600	Dewey, W. A., Tully,	Tully, W. A. Dewey,
836	Gollman, J. W., Wellsville,	Wellsville, J. W. Gollman,
589	Amos, Jacob, Syracuse,	Liverpool, Ludwig Scheidt,
565	Denick, E. D., Syracuse,	Syracuse, E. D. Denick,
564	Harding, J. B., Syracuse,	Syracuse, J. B. Harding,
860	Holland, Stephen, Hornellsville,	Hornellsville, S. Holland,
595	Russ, A. E., Phoenix,	Phoenix, A. E. Russ,
857	Simmons & Howell, Hornellsville,	H'nellsville, Simmons & Howell
855	Terry, Eugene, Hornellsville,	Hornellsville, E. Terry,
576	Clark & Mercer, Baldwinsville,	Baldwinsville, Clark & Mercer,
571	Farrington Bros., Syracuse,	Syracuse, Farrington Bros.,
557	Frier, Henry, Syracuse,	Syracuse, H. Frier,
1074	Grandin, D. H., Jamestown,	Jamestown, W. J. Heath,
578	Hart, C. E., Baldwinsville,	Baldswinville, C. E. Hart,
558	McCarthy & Smith, Syracuse,	Syracuse, McCarthy & Smith,
568	Meager Bros., Syracuse,	Syracuse, Meager Bros.,
593	Parker, A. C., Phoenix,	Phoenix, A. C. Parker,
555	Patterson, L. L., & Co., Syracuse,	Syracuse, L. L. Patterson & Co.
556	Porter Bros., Syracuse,	Syracuse, Porter Bros.,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
827	Bran, fancy,	15.6		4.8		8.5	$20.00
956	"	16.1		4.4		7.8	19.00
1070	† "	14.0		3.8		13.4	
1072	† "	12.6		3.3		14.3	18.50
892	"	16.1		3.7		8.8	20.00
877	"	15.6		5.2		10.1	18.00
772	"	16.5		4.8		11.1	17.00
747	" spring wheat,	16.1		4.7		10.5	18.00
893	"	15.9		3.7		7.5	19.00
804	"	15.6		5.3		10.9	20.00
735	" " "	16.3		5.0		12.0	20.00
933	"	16.3		4.1		8.6	20.00
1020	" winter wheat,	17.1		4.4		6.7	21.00
751	"	17.5		4.8		11.2	20.00
792	"	17.4		5.2		11.8	18.00
917	"	16.4		5.1		10.2	
1024	" spring wheat,	15.0		4.8		11.2	19.00
788	"	14.8		4.2		9.4	20.00
830	"	15.9		4.9		9.6	20.00
1056	" blended,	15.4		4.7		9.4	19.00
736	" spring wheat,	15.8		4.9		11.0	18.00
758	" coarse,	15.6		5.0		11.4	18.00
762	" fine,	15.8		4.6		10.6	19.00
1050	" spring wheat,	14.9		4.9		10.4	19.00
819	" winter "	16.3		4.0		8.8	19.50
752	"	17.3		4.9		11.1	20.00
1041	" oat,	13.6		5.3		17.8	10.00
600	† " barley meal and hominy,	16.3		5.7		10.2	22.00
836	† " meal and Manhattan gluten,	15.0		*			24.00
589	" corn meal and middlings,	11.7		4.3		4.2	27.00
565	" " " " "	13.6		3.6		10.5	23.00
564	" " " " "	14.1		4.8		4.8	24.00
860	" " " " " No. 2,	13.0		4.1		5.1	
595	" " " " "	15.4		5.4		5.6	24.00
857	" " " " " No. 2,	13.9		3.5		5.8	24.00
855	" " " " "	14.6		4.7		7.7	24.00
576	Bran and corn meal,	13.0	12.05	3.7	4.15	3.2	23.00
571	" " " "	13.1	12.0	4.2	3.5	6.1	24.00
557	" " " "	14.4		4.8		6.2	23.00
1074	" " " "	9.7		3.2		8.2	19.00
578	" " " "	13.1		4.0		5.4	23.00
558	" " " "	13.8		4.6		5.0	25.00
568	" " " "	13.1	12.0	4.3	3.5	4.9	26.00
593	" " " "	13.1		4.1		9.8	23.00
555	" " " "	13.8		4.5		5.4	23.00
559	" " " "	12.5		4.1		8.2	24.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
570	Rosenbloom, J., Syracuse,	Syracuse, J. Rosenbloom,
791	Tomlison, Geo., & Son, Perry,	Perry, G. Tomlison & Son,
843	Tompkins, J. B., & Son, Wellsville,	Wellsville, W. Carpenter & Co.,
832	Wetherby & Keller, Wellsville,	Wellsville, Wetherby & Keller,
794	Martin, J. J., Perry,	Perry, J. J. Martin,
566	Meager Bros., Syracuse,	Syracuse, Meager Bros.,
778	Moulton, W. E., & Co., Alexander,	Alexander, W. E. Moulton & Co.
790	Tomlison, Geo., & Son, Perry,	Perry, G. Tomlison & Son,
561	Porter Bros, Syracuse,	Syracuse, Porter Bros.,
1065	Brooks Elevator Co., Minneapolis, Minn.,	Buffalo, Heathfield & Washburn
773	Urban Mill Co., Buffalo,	Attica, Attica Mills,
759	West Avenue Mill Co., Attica,	Attica, J. P. Frey,
964	Grandin, D. H., Jamestown,	Jamestown, D. H. Grandin,
939	Waterman, J. L., Westfield,	Westfield, J. L. Waterman,
540	American Hominy Co., Chicago, Ill.,	Kingston, Wilson & Wolven,
544	" " " " "	Saugerties, F. G. Phelps,
545	" " " " "	Hudson, Downing & Bogardus,
764	" " " " "	Attica, J. P. Frey,
902	" " " " "	Hamburg, O. N. Conger,
992	" " " " "	Buffalo, Husted M. & Elev. Co.,
1023	" " " " "	Buffalo, Diamond Mills,
550	Buffalo Cereal Co., Buffalo,	Syracuse, Jacob Amos,
673	" " " "	Oneonta, Morris Bros.,
1027	" " " "	Buffalo, Buffalo Cereal Co.,
1038	" " " "	" " " "
605	Chapin & Co., Buffalo,	Homer, Newton & Co.,
697	" " "	Richfield Springs, W. B. Ward,
810	" " "	Olean, Olean Mills,
817	" " "	Olean, Acme Milling Co.,
913	" " "	East Aurora, Griggs & Ball,
617	Hunter Bros., St. Louis, Mo.,	Binghamton, Emp. G. & E. Co.,
639	" " " "	Norwich, Bushley & McNitt,
719	Patent Cereals Co., Geneva,	Cazenovia, Atwell & Son,
525	Payne, W. H., & Son, New York,	New York, W. H. Payne & Son
652	Shellabarger Mill & Elev. Co., Decatur, Ill.,	Delhi, Gleason & Kiff,
599	Suffern, Hunt & Co., Decatur, Ill.,	Tully, W. A. Dewey,
620	" " " " "	Norwich, H. O. Hale,
722	" " " " "	Marathon, Marathon Roll. Mills
806	" " " " "	Olean, Empire Mills,
615	Toledo Elevator Co., The, Toledo, O.,	Binghamton, G. Q. Moon & Co.,
664	" " " " " "	Oneonta, Morris Bros.,
1069	U. S. Frumentum Co., Detroit, Mich.,	Buffalo, Hydraulic Mill Co.,
626	Cerealine Mfg. Co., Indianapolis, Ind.,	Oxford, French & Mead,
641	" " " " "	Sidney, Sidney F. & F. Co.,
733	Adams, Robert, Batavia,	Batavia, R. Adams,
769	Attica Mills, Attica,	Attica, Attica Mills,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
570	Bran and meal,	15.6		6.2		6.8	$24.00
791	" "	11.6		4.3		5.5	24.00
843	" "	10.5		*			26.00
832	" "	10.7		2.7		2.9	25.00
794	" corn and oats,	11.8		4.4		6.7	27.00
566	" " " "	10.9		4.4		6.5	30.00
778	" " " "	9.4		4.2		6.5	26.00
700	" " " "	11.0		3.4		6.0	27.00
561	" and oats,	14.6		4.3		8.0	28.00
1065	Screenings, wheat,	14.4		3.3		5.9	16.00
773	" "	14.1		4.7		6.2	16.00
759	" "	15.9		4.6		7.4	16.00
964	" and wheat feed,	12.8		1.8		6.8	21.00
939	Wheat, rye and oat feed,	10.4		*			28.00
540	Hominy feed,	11.8	10.24	9.4	7.72	4.8	26.00
544	" "	10.9	10.24	9.4	7.72	4.6	26.00
545	" "	11.3	10.24	9.5	7.72	4.3	25.00
764	" "	11.2	10.24	9.6	7.72	4.4	25.00
902	" "	11.3	10.24	9.4	7.72	4.3	24.00
992	" "	9.9	10.24	8.2	7.72	3.8	21.50
1023	" "	10.6	10.24	9.6	7.72	3.1	22.00
550	" "	11.4	10.5	9.5	8.5	4.8	24.00
673	" "	11.4	10.5	9.3	8.5	4.4	25.00
1027	" " white,	9.9	10.5	7.5	8.5	3.6	20.00
1038	" " yellow,	10.1	10.5	8.4	8.5	4.3	20.00
605	" " Green diamond,	9.1	11.0	7.0	8.0	9.3	24.00
697	" " " "	10.3	11.0	8.1	8.0	7.4	25.00
810	" " " "	11.1	11.0	8.9	8.0	5.2	28.00
817	" " " "	10.6	11.0	8.5	8.0	7.1	23.00
913	" " " "	10.4	11.0	8.5	8.0	7.3	22.00
617	" "	11.4	11.02	10.2	7.70	5.2	22.00
639	" "	11.6	11.02	9.7	7.70	4.6	25.00
719	" "	12.2	11.46	9.7	9.30	4.6	24.00
525	" "	10.6	11.49	8.3	8.0	3.5	
652	" " Shellabarger's,	11.1	11.14	9.3	9.02	4.4	24.00
599	" "	11.7	11.02	9.8	7.84	5.1	26.00
620	" "	11.1	11.02	8.6	7.84	4.1	25.00
722	" "	10.4	11.02	8.7	7.84	4.5	25.75
806	" "	10.2	11.02	7.9	7.84	5.5	22.00
615	" "	10.2	10.93	7.8	7.05	7.7	24.00
664	" "	10.2	10.93	7.5	7.05	6.6	24.00
1069	" "	9.7	11.63	7.3	8.66	4.6	23.00
626	† Cerealine food, No. 2,	12.6	10.82	10.3	8.03	3.9	26.00
641	† " " "	12.8	10.82	10.7	8.03	3.8	24.00
733	Corn meal,	9.4		3.6		1.7	28.00
769	" "	9.7		4.0		1.8	26.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
927	Crouch Bros. Co., Erie, Pa.,	Dunkirk, W. Rueckert,
784	Diamond Mills, Buffalo,	Warsaw, Montgomery Bros.,
821	Empire Mills, Olean,	Olean, L. J. Miller & Son,
1071	Grandin, D. H., Jamestown,	Jamestown, A. J. Martin,
989	Husted Mill'g & Elevator Co., Buffalo,	Buffalo, Husted M. & Elev. Co.,
875	" " "	Salamanca, E. J. Sowl,
802	Hydraulic Milling Co., Buffalo,	Bliss, E. E. Buck,
782	Moulton, W. E., & Co., Alexander,	Alexander, W. E. Moulton & Co.
841	American Cereal Co., Chicago, Ill.,	Wellsville, C. B. Hyslip,
882	Toledo Grain & Milling Co., Toledo, O.,	Little Valley, G. W. Griffith,
768	Attica Mills, Attica,	Attica, Attica Mills,
800	Bliss Milling Co., Bliss,	Bliss, Bliss Milling Co.,
1014	Diamond Mills, Buffalo,	Buffalo, Diamond Mills,
1053	Engle, A. A., Buffalo,	Buffalo, A. A. Engle,
760	Husted Mills & Elevator Co., Buffalo,	Attica, J. P. Frey,
793	Martin, J. J., Perry,	Perry, J. J. Martin,
1049	Urban Mills, Buffalo,	Buffalo, Urban Mills,
546	Barber & Bennett, Albany,	Albany, Barber & Bennett,
596	Chapman, T. J., Skaneateles,	Skaneateles, T. J. Chapman,
528	Clark & Allen, New York,	New York, Clark & Allen,
577	Clark & Mercer, Baldwinsville,	Baldwinsville, Clark & Mercer,
603	Darby, W. H., Homer,	Homer, W. H. Darby,
598	Globe Milling Co., Camillus,	Camillus, Globe Milling Co.,
579	Hart, C. E., Baldwinsville,	Baldswinsville, C. E. Hart,
580	Head, G. W., & Co., Utica,	Utica, G. W. Head & Co.,
588	Healey, C. W., New Hartford,	New Hartford, C. W. Healy,
657	Haverly, A. A., Walton,	Walton, A. A. Haverly,
683	Kilts, W. J., Cobleskill,	Cobleskill, W. J. Kilts,
587	McLoughlin Bros., Utica,	Utica, McLoughlin Bros.,
604	Newton & Co., Homer,	Homer, Newton & Co.,
584	Ogden & Clark, Utica,	Utica, Ogden & Clark,
554	Patterson, L. L., & Co., Syracuse,	Syracuse, L. L. Patterson & Co.
609	Smith, C. O., Cortland,	Cortland, C. O. Smith,
597	Southwell, D., Mottville,	Mottville, D. Southwell,
608	Webster & Son, Cortland,	Cortland, Webster & Son,
646	Wright, John, Walton,	Walton, J. Wright,
948	Chautauqua Lake Mills, Mayville,	Mayville, Chautauqua L. Mills,
925	Crouch Bros. Co., Erie, Pa.,	Dunkirk, Wm. Rueckert,
928	" " "	Dunkirk, Frank May & Co.,
1011	Diamond Mills, Buffalo,	Buffalo, Diamond Mills,
1075	Grandin, D. H., Jamestown,	Jamestown, Axel Swanson,
945	Harter, I., Co., Toledo, O.,	Brocton, C. P. Lawson,
851	Hood & Bradley, Belmont,	Belmont, Hood & Bradley,
978	Howard, C. J., Gowanda,	Gowanda, C. J. Howard,
560	Husted Mill'g & Elevator Co., Buffalo,	Syracuse, Porter Bros.,
572	" " "	Syracuse, J. C. Surbeck,
638	" " "	Norwich, Bushley & McNitt,
716	" " "	Cazenovia, L. M. Woodworth,
728	" " "	DeRuyter, J. W. West,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
927	Corn meal,	8.1		1.9		1.7	$24.00
784	† “ “	8.6		3.6		7.9	27.00
821	“ “	9.2		4.0		2.0	29.00
1071	“ “	8.0		3.2		3.5	
989	“ “ A,	7.9		*			22.00
875	“ “ B,	9.0		*			23.00
802	“ “	9.4		3.8		2.0	27.00
782	“ “	9.7		3.0		1.7	28.00
841	Feed meal, corn,	11.1		6.5			28.00
882	“ “ ordinary,	8.2	8.31	3.4	3.6	4.6	25.00
768	Oats, ground,	9.4		4.6		9.9	26.00
800	“ “	9.9		3.9		8.4	23.00
1014	“ “	9.2		4.3		12.0	24.00
1053	“ “	11.3		4.3		11.1	27.00
760	“ “	11.9		5.2		8.4	25.00
793	“ “	10.9		4.7		10.1	28.00
1049	“ “	12.6		4.2		9.4	29.00
546	Corn and oats, ground,	9.8		4.0		6.0	25.50
596	“ “ “ “	9.6		3.9		3.4	30.00
528	“ “ “ “	10.3		4.6		3.6	25.00
577	“ “ “	10.4		3.6		3.5	27.00
603	“ “ “	8.6		3.5		8.6	30.00
598	“ “ “	9.8		4.1		4.6	26.00
579	“ “ “ “	10.1		3.4		4.5	27.00
580	“ “ “	11.3		5.5		5.6	28.00
588	“ “ “	11.3		4.0		6.2	28.00
657	“ “ “	11.4		3.0		4.1	30.00
683	“ “ “	9.9		3.8		4.9	28.00
587	“ “ “	10.7		4.4		5.1	27.00
604	“ “ “	9.1		3.7		6.1	27.00
584	“ “ “	10.2		4.3		6.0	28.00
554	“ “ “ “	10.6		3.9		3.8	29.00
609	“ “ “	10.2		4.0		4.1	29.00
597	“ “ “ “	9.1		3.5		8.1	28.00
608	“ “ “	9.8		3.8		5.3	26.00
646	“ “ “	10.3		4.7		3.8	30.00
948	Corn and oat chop,	9.6		2.8		3.9	28.00
925	“ “ “ “	9.4		*			26.00
928	“ “ “ “	9.4		*			25.00
1011	“ “ “ “	8.1	9.44	*	4.78		17.00
1075	“ “ “ “	8.5		3.3		5.9	
945	“ “ “ “ No. 1,	8.8		*			25.00
851	“ “ “ “	9.6		4.2		6.2	25.00
978	“ “ “ “	10.5		*			25.00
560	“ “ “ “ B,	9.7	8.28	4.9	2.75	7.7	24.00
572	“ “ “ “ Monarch,	9.7	10.4	4.3	3.27	8.3	25.00
638	“ “ “ “ “	9.3	10.4	3.7	3.27	10.2	22.00
716	“ “ “ “ “	9.1	10.4	3.6	3.27	10.8	22.00
728	“ “ “ “ “	9.9	10.4	5.0	3.27	8.0	25.00

Collection No.	Name and address of manufacturer or jobber.	Samples at
763	Husted Mill'g & Elevator Co., Buffalo,	Attica, J. P. Frey,
897	" " "	Hamburg, T. H. Gressman,
899	" " "	Hamburg, A. N. Conger,
903	" " "	Lancaster, Adolf Bros.,
988	" " "	Buffalo, Husted M. & Elev. Co.,
569	Imperial Grain & Milling Co., Toledo, O.,	Syracuse, Meager Bros.,
828	Lawn, S. R., Cuba,	Cuba, S. R. Lawn,
808	Olean Mills, Olean,	Olean, Olean Mills,
809	" " "	" " "
854	Strait, J. H., Mill Co., Canisteo,	Hornellsville, Eugene Terry,
881	Toledo Grain & Mill Co., Toledo, O.,	Little Valley, G. W. Griffith,
947	" " " " " "	Brocton, W. A. Miles & Son,
844	Tompkins, J. B., & Son, Wellsville,	Wellsville, J. B. Tompk's & Son
951	Wilkenson, Gaddis & Co., Sherman,	Sherman, Wilk'n, Gaddis & Son
815	Acme Milling Co., Olean,	Olean, Acme Milling Co.,
549	American Cereal Co., Chicago, Ill.,	Syracuse, Jacob Amos,
627	" " " "	Oxford, Fletcher & Corbin,
658	" " " "	Oneonta, Ford & Rowe,
695	" " " "	Worcester, P. H. Platts,
701	" " " "	Canastota, F. T. Benjamin,
822	" " " "	Olean, Olean Supply Co.,
840	" " " "	Wellsville, C. B. Hyslip,
745	Ballard, E. F., Batavia,	Batavia, E. F. Ballard,
890	Benson, A. T., Cattaraugus,	Cattaraugus, A. T. Benson,
1028	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
1036	" " " "	" " " "
1037	" " " "	" " " "
563	Diamond Mills, Buffalo,	Syracuse, F. P. Williamson,
717	" " "	Cazenovia, L. M. Woodworth,
783	" " "	Warsaw, Montgomery Bros.,
914	Godfrey, E. E., East Aurora,	East Aurora, E. E. Godfrey,
575	Great Western Cereal Co., Chicago, Ill.,	Syracuse, E. S. Beard,
777	" " " " " "	Attica, B. F. Bennett,
970	" " " " " "	Jamestown, B. R. Welton,
590	" " " " " "	Phoenix, A. C. Parker,
709	" " " " " "	Oneida, E. J. Buyea,
542	" " " " " "	Kingston, Wilson & Wolven,
869	" " " " " "	Salamanca, C. F. Buckmaster,
912	Griggs & Ball, East Aurora,	East Aurora, Griggs & Ball,
585	Hunter Bros., St. Louis, Mo.,	Utica, Ogden & Clark,
622	" " " "	Norwich, R. A. Weed,
724	" " " "	Marathon, J. H. Seeber & Son,
1001	H-O Company, Buffalo,	Buffalo, H-O Co.,
859	Holland, Stephen, Hornellsville,	Hornellsville, S. Holland,
991	Husted Mill & Elevator, Buffalo,	Buffalo, Husted M. & Elev. Co.
537	Illinois Cereal Co., Lockport, Ill.,	Peekskill, G. F. Cooley,
858	" " " " "	H'nellsville, Simmons & Howell
795	Martin, J. J., Perry,	Perry, J. J. Martin,
527	Morgan, Thos., Long Island City,	L. I. City, Thos. Morgan,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
763	Corn and oat chop, Monarch,	9.6	10.4	4.5	3.27	8.3	$23.00
897	“ “ “ “ “	8.8	10.4	3.9	3.27	10.0	23.00
899	“ “ “ “ “	8.8	10.4	3.8	3.27	8.5	19.00
903	“ “ “ “ “	8.4		*			22.00
988	“ “ “ “ “	7.4	10.4	2.3	3.27	13.6	18.00
569	“ “ “ “ No. 1,	9.7	8.17	4.0	5.33	6.2	30.00
828	“ “ “ “	8.6		4.4		8.6	26.00
808	“ “ “ “ special,	9.0	8.58	*	4.86		28.00
809	“ “ “ “	8.7		3.7		10.7	26.00
854	“ “ “ “	8.7		*			25.00
881	“ “ “ “ A,	9.1		3.5		7.2	25.00
947	“ “ “ “ Keystone,	12.1	9.53	5.5	5.73	5.8	26.00
844	“ “ “ “	9.1		3.0		5.9	26.00
951	“ “ “ “	9.4		3.9		5.3	24.00
815	Corn and oat feed, special,	10.4		4.0		4.4	25.00
549	“ “ “ “ Victor,	8.8	9.0	4.2	4.0	11.2	21.00
627	“ “ “ “ “	9.7	9.0	4.4	4.0	11.3	26.00
658	“ “ “ “ “	9.3	9.0	4.1	4.0	10.8	21.00
695	“ “ “ “ “	8.9	9.0	4.2	4.0	10.8	19.00
701	“ “ “ “ “	9.9	9.0	4.5	4.0	9.8	23.00
822	“ “ “ “ “	9.1	9.0	4.0	4.0	11.6	30.00
840	“ “ “ “ “	9.9	9.0	4.3	4.0	12.1	23.00
745	“ “ “ “	8.1		*			25.00
890	“ “ “ “	9.6		3.1		8.2	22.00
1028	“ “ “ “	8.9	9.5	5.0	4.5	17.3	20.00
1036	“ “ “ “ Banner,	8.2	8.5	4.1	5.0	13.1	20.00
1037	“ “ “ “ special No. C,	7.9	8.5	4.8	4.5	12.0	13.50
563	“ “ “ “	8.7	9.44	4.6	4.78	11.1	25.00
717	“ “ “ “	9.3	9.44	4.5	4.78	9.3	22.00
783	“ “ “ “	8.2	9.44	4.3	4.78	12.9	25.00
914	“ “ “ “	9.0		*			26.00
575	“ “ “ “ Boss,	9.4	8.27	5.0	3.64	11.7	23.00
777	“ “ “ “ “	8.4	8.27	4.1	3.64	13.3	20.00
970	“ “ “ “ “	7.3	8.27	2.9	3.64	17.5	22.00
590	“ “ “ “ Durham,	6.3	9.46	1.7	3.92	19.3	22.00
709	“ “ “ “ “	8.9	9.46	4.8	3.92	14.9	20.00
542	“ “ “ “ Excelsior,	9.9	8.21	5.2	4.58	11.2	25.00
869	“ “ “ “ “	9.9	8.21	4.9	4.58	9.3	19.00
912	“ “ “ “	9.2		3.6		5.8	28.00
585	† “ “ “ “ Ned,	9.4	9.0	5.1	5.0	13.7	23.00
622	† “ “ “ “ “	8.9	9.0	5.0	5.0	13.2	20.00
724	† “ “ “ “ “	9.3	9.0	5.4	5.0	15.6	19.00
1001	“ “ “ “ De-Fi,	10.1	8.3	3.3	3.0	15.5	21.50
859	“ “ “ “ No. 1,	10.2		*			26.00
991	“ “ “ “	10.9		*			23.00
537	“ “ “ “ Anchor,	9.2	9.5	3.1	4.0	11.4	22.00
858	“ “ “ “ “	9.4	9.5	2.6	4.0	13.2	23.00
795	“ “ “ “	9.8		*			29.00
527	“ “ “ “	9.4		3.7		2.1	27.60

Collection No.	Name and address of manufacturer or jobber.	Sampled at
681	Oneonta Milling Co., Oneonta,	Oneonta, Oneonta Milling Co.,
825	Phelps & Sibley, Cuba,	Cuba, Phelps & Sibley,
921	Saunders, G. P., Dunkirk,	Dunkirk, G. P. Saunders,
895	Schoefflin, J., Hamburg,	Hamburg, J. Schoefflin,
856	Simmons & Howell, Hornellsville,	H'nellsville, Simmons & Howell
871	Toledo Grain & Milling Co., Toledo, O.	Salamanca, C. F. Buckmaster,
922	" " " " " "	Dunkirk, J. W. O'Brien,
731	Adams, Robert, Batavia,	Batavia, Robert Adams,
667	Oneonta Milling Co., Oneonta,	Unadilla, S. H. Chapin,
669	" " " "	Otego, Oneonta Milling Co.,
676	American Cereal Co., Chicago, Ill.,	Oneonta, Oneonta Milling Co.,
704	" " " "	Camden, Orr & Gardner,
846	" " " "	Wellsville, J. B. Tompk's & Son
1064	" " " "	Buffalo, Lack. Mill & Elev. Co.
1034	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
1035	" " " "	" " " "
677	Great Western Cereal Co., Chicago, Ill.,	Oneonta, Oneonta Milling Co.,
995	" " " " " "	Buffalo, Husted M. & Elev. Co.
718	Diamond Mills, Buffalo,	Cazenovia, L. M. Woodworth,
786	" " "	Warsaw, D. E. Keeney & Son,
1016	" " "	Buffalo, Diamond Mills,
649	Chester Mills, New York,	Delhi, Coöperative Store,
659	" " " "	Oneonta, Ford & Rowe,
686	" " " "	Middleburg, W. C. West,
998	" " " "	Buffalo, Husted M. & Elev. Co.
997	Strong, Lefferts Co., New York,	" " " " "
581	American Cereal Co., Chicago, Ill.,	Utica, G. W. Head & Co.,
621	" " " "	Norwich, R. D. Eaton,
837	" " " "	Wellsville, Scov., Brown & Co.
842	" " " "	Wellsville, C. B. Hyslip,
968	" " " "	Jamestown, Hayward & Co.,
874	" " " "	Salamanca, E. J. Sowl,
738	Salway, E. J., Batavia,	Batavia, E. J. Salway,
594	Pierce & Pendergast, Phoenix,	Phoenix, Pierce & Pendergast,
732	Adams, Robert, Batavia,	Batavia, Robert Adams,
574	Beard, E. S., Syracuse,	Syracuse, E. S. Beard,
742	Colquhoun & Waldruff, Batavia,	Batavia, Colquhoun & Waldruff
614	Doolittle, Luke, Binghamton,	Binghamton, Luke Doolittle,
906	Mook, P. P., Lancaster,	Lancaster, P. P. Mook,
688	Rickard, A. S., Schoharie,	Schoharie, A. S. Rickard,
774	Attica Mills, Attica,	Attica, Attica Mills,
868	Morris & Seeber, Hornellsville,	Hornellsville, Morris & Seeber,
942	Mathews, Vernon, Brocton,	Brocton, V. Mathews,
750	Douglass, C. H. & H. N., Batavia,	Batavia, C. H. & H. N. Douglass
814	Acme Milling Co., Olean,	Olean, Acme Milling Co.,
548	Amos, Jacob, Syracuse,	Syracuse, Jacob Amos,
684	Becker & Co., Central Bridge,	Central Bridge, Becker & Co.,
538	Cooley, G. F., Peekskill,	Peekskill, G. F. Cooley,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
681	Corn and oat feed, Arrow,	8.6	9.0	3.7	3.75	6.0	$26.00
825	" " " " pure,	9.9		3.7		5.3	25.00
921	" " " "	10.0		4.0		4.3	27.00
895	" " " "	10.6		4.0		4.6	26 00
856	" " " " No. 1,	8.5		3.0		7.6	26.00
871	" " " "	8.9		3.3		4.5	26.00
922	" " " "	9.0		*			24.00
731	" " " " provender,	9.9		3.8		3.9	27.00
667	" " " " " choice,	10.1	8.75	3.3	3.5	10.7	21.00
669	" " " " " "	10.7	8.75	3.6	3.5	9.9	20.00
676	Oat feed, Vim,	6.4	7.5	2.7	2.75	26.1	15.50
704	" " "	7.6	7.5	3.2	2.75	22.8	20.00
846	" " "	7.1	7.5	2.9	2.75	23.9	12.00
1064	" " "	6.8	7.5	2.6	2.75	25.4	12.00
1034	" " Standard,	7.6	7.0	3.0	3.0	24.5	13.50
1035	" " special,	10.3		4.7		13.9	13.50
677	" " Cream,	6.7	6.97	2.4	2.93	24.1	15.50
995	" " Royal,	6.3	7.53	2.2	3.63	25.9	13.40
718	Empire State cow feed,	13.8	14.96	3.7	3.48	16.1	19.00
786	" " " "	13.8	14.96	3.4	3.48	15.6	18.00
1016	" " " "	11.4	14.96	3.5	3.48	16.4	17.50
649	† Chester stock food,	9.6	9.5	4.5	4.0	9.2	25.00
659	† " " "	9.1	9.5	3.8	4.0	10.1	23.00
686	† " " "	10.1	9.5	5.0	4.0	7.8	25.00
998	† " " "	8.1	9.5	3.2	4.0	10.7	16.50
997	Lenox stock food,	8.6	9.88	3.0	3.27	8.2	16.50
581	Schumacher's stock food,	11.2	13.0	4.1	5.0	12.0	26.00
621	" " "	12.2	13.0	3.5	5.0	10.0	30.00
837	" " "	12.1	13.0	4.8	5.0	10.7	25.00
842	" " "	12.2	13.0	4.9	5.0	9.6	27.00
968	" " "	11.7	13.0	4.7	5.0	10.4	26.00
874	Corn, oats and barley feed,	12.1	13.0	4.7	5.0	10.1	23.00
738	" " " " "	10.4		2.9		4.4	28.00
594	Oats and wheat ground,	10.9		3.3		7.8	25.00
732	" " rye,	10.3		2.8		5.1	25.00
574	" rye and corn,	11.3		3.4		3.4	27.00
742	" " " "	10.1		3.8		5.9	28.00
614	" " " "	10.1		3.5		4.9	28.00
906	" " " "	10.1		*			28.00
688	" " " "	13.0		2.5		5.1	27.00
774	" " corn and barley,	9.8		4.0		6.4	21.00
868	" " and barley,	9.6		4.1		9.3	27.00
942	" corn and corn bran,	10.2		*			26.00
750	† " " " Boss horse and cattle feed,	8.9		3 2		10.7	25.00
814	Acme feed: hominy, corn and oat hulls,	9.4	8.5	4.7	4.5	11.0	23.00
548	Ground feed,	9.8		3.5		4.2	27.00
684	Mixed feed: corn, oats, rye, barley and buckwheat,	10.1		3.3		5.1	26.00
538	† Special order: corn, oats, hominy and barley meal,	10.4		5.7		10.3	25.00

Collection No.	Name and address of manufacturer or jobber.	Sampled at
805	Empire Mills, Olean,	Olean, Empire Mills,
820	" " "	Olean, L. J. Miller & Son,
829	Phelps & Sibley, Cuba,	Cuba, Phelps & Sibley,
1043	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
850	Tompkins, J. B. & Son, Wellsville,	Wellsville, J. B. Tompk's & Son
552	Oneonta Milling Co., Oneonta,	Syracuse, Jacob Amos,
980	Darrison, J. S., Lockport,	Lockport, J. S. Darrison,
765	West Avenue Mill Co., Attica,	Attica, J. P. Frey,
1059	Curtis, C. G., Buffalo,	Buffalo, C. G. Curtis Co.,
1062	Kam Malting Co., Buffalo,	Buffalo, Kam Malting Co.,
625	American Cereal Co., Chicago, Ill.,	Oxford, French & Mead,
663	" " " "	Oneonta, Morris Bros.,
703	" " " "	Camden, Orr & Gardner,
823	" " " "	Olean, Olean Supply Co.,
986	" " " "	Lockport, J. R. Regnal,
1031	Buffalo Cereal Co., Buffalo,	Buffalo, Buffalo Cereal Co.,
661	H-O Company, Buffalo,	Oneonta, Morris Bros.,
1000	" " "	Buffalo, H-O Co.,
533	Midland Feed Co., Kansas City, Mo.,	N. Y., Exc'r W. & P. Sup. Co.,
535	" " " "	" " " " "
532	" " " "	" " " " "
534	" " " "	" " " " "
1008	Cypher Incubator Co., Buffalo,	Buffalo, Cypher Incubator Co.,
611	Harding, G. L., Binghamton,	Binghamton, G. L. Harding,
536	Star Incubator & Brooder Co., New York,	N.Y. Star Incu. & Brooder Co.,
662	H-O Company, Buffalo,	Oneonta, Morris Bros.,
1003	" " "	Buffalo, H-O Co.,
1004	" " "	" " "
531	Mosley & Motley Milling Co., Rochester,	New York, Clark & Allen,
698	Barwell, J. W., Waukegan, Ill.,	Richfield Springs, W. B. Ward,
937	" " " "	Westfield, H. V. Herrick,
944	" " " "	Brocton, V. Mathews,
668	Bowker Fertilizer Co., New York,	Unadilla, J. W. Van Cott & Son
863	" " " "	Hornellsville, S. Holland,
1007	" " " "	Buffalo, Harvey Seed Co.,
636	Romaine, DeWitt, New York,	Waterville, Hubbard & King,
711	" " "	N. Woodstock, E.E. Hatch & Co.
873	" " "	Salamanca, C. F. Buckmaster,
985	Armour & Co., Chicago, Ill.,	Lockport, J. O. Rignal,
612	Harding, G. L., Binghamton,	Binghamton, G. L. Harding,
1009	" " "	Buffalo, DesMoine Incub'r Co.,
1005	Swift & Co., Chicago, Ill.,	Buffalo, Harvey Seed Co.,
982	Darling & Co., Chicago, Ill.,	Lockport, John Young,
607	Finn's, H., Sons, Syracuse,	Cortland, C. M. Jennings,
637	" " "	Waterville, Hubbard & King,
610	Harding, G. L., Binghamton,	Binghamton, G. L. Harding,
767	Harvey Seed Co., Buffalo,	Attica, J. P. Frey,
1006	McCallom & Co., Dayton, O.,	Buffalo, Harvey Seed Co.,
987	Armour & Co., Chicago, Ill.,	Lockport, J. R. Rignal,

Collection No.	Name of feed.	Protein. Found.	Protein. Guaranteed.	Fat. Found.	Fat. Guaranteed.	Crude fiber found.	Price per ton.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
805	Empire feed: corn and oats,	7.7	7.63	2.9	2.97	11.7	$26.00
820	" " " " "	8.1	7.63	3.0	2.97	10.6	28.00
829	Vanity fair: screenings,	11.7		2.8		9.3	
1043	Oat hulls, ground,	2.9		1.0		30.7	10.00
850	Buckwheat feed: corn, hulls and screenings,	11.1		3.3		17.5	10.00
552	Rye flour,	17.1		3.0		0.9	30.00
980	" feed,	9.9		1.7		2.2	23.00
765	" "	11.4		2.6		3.2	25.00
1059	Barley skimmings,	13.3		3.5		11.4	24.00
1062	" "	13.6		3.8		11.0	
625	Poultry food, American,	14.3	14.0	6.0	4.5	4.6	30.00
663	" " "	14.4	14.0	6.0	4.5	4.7	32.00
703	" " "	14.1	14.0	5.8	4.5	4.5	36.00
823	" " "	14.1	14.0	6.0	4.5	5.1	‡18.00
986	" " "	14.6	14.0	5.7	4.5	4.8	30.00
1031	" "	17.3	17.0	4.9	5.0	4.0	30.00
661	" " H-O,	18.0	17.0	5.1	5.5	4.7	37.00
1000	" " "	16.6	17.0	4.9	5.5	4.9	32.00
533	†Egg & feather producing food, No.4	17.5	20.3	4.5	4.12	6.4	56.25
535	†Grenadier meal,	16.9	16.0	8.8	6.4	2.4	87.50
532	†Chick food, growing, No. 2,	17.0	20.03	4.4	4.12	6.6	56.25
534	† " " nursery, No. 1,	14.1	13.9	5.1	5.4	3.4	56.25
1008	" " Cypher's,	9.0		*			40.00
611	† " " Baby,	14.5	15.0	7.3	7.75	3.4	50.00
536	" " Star, Specific, No. 7,	11.4		2.3		2.9	70.00
662	Scratching feed, H-O,	13.1	12.0	3.4	3.0	2.6	40.00
1003	" " "	10.7	12.0	2.7	3.0		34.00
1004	Pidgeon feed, "	11.8		3.4			35.00
531	Duck feed, low grade flour,	16.4		2.9			28.00
698	§ Poultry meats, Blatchford's,	29.9	33.0	8.1	10.0		70.00
937	" " "	28.9	33.0	7.8	10.0		80.00
944	" " "	29.6	33.0	6.3	10.0		100.00
668	Animal meal,	31.6	30.0	20.3	5.0		
863	" "	27.9	30.0	14.5	5.0		50.00
1007	" "	34.5	30.0	7.9	5.0		45.00
636	Boiled beef and bone,	40.1	45.0	15.1	15.0		40.00
711	" " " "	30.4	45.0	16.3	15.0		50.00
873	" " " "	27.5	45.0	12.4	15.0		60.00
985	Meat meal,	56.6	50.0	16.8	10.0		50.00
612	" "	32.3	49.0	17.2	19.0		45.00
1009	" "	43.3	49.0	18.1	19.0		40.00
1005	† " "	64.6	60.0	21.2	5.0		45.00
982	Beef scraps, ground,	54.8	50.0	13.2	10.0		50.00
607	" "	41.1	45.88	18.2	20.4		50.00
637	" "	39.3	45.88	16.1	20.4		65.00
610	" " high grade,	48.8	42.0	20.2	30.0		45.00
767	† " "	61.4		5.6			40.00
1006	† " " ground,	60.0	50.0	10.9	9.0		45.00
987	Blood meal,	84.1	87.0	0.3	0.2		80.00

* Sample became too moldy to determine fat content. † Not licensed in this State in 1903.
‡ Guaranteed on a water-free basis. § A condimental preparation.

The samples analyzed may be classified as follows:

TABLE III.—CLASSIFICATION OF SAMPLES ANALYZED.

Name of feed.	No. samples.	No. brands.
Cottonseed meal	15	8
Distiller's grains	18	8
Brewer's grains	2	2
Linseed cake, ground	4	2
Linseed oil meal	23	10
Gluten meal	2	2
Gluten feed	22	7
Hominy feed	28	11
Malt sprouts	7	5
Germ oil meal	2	1
Oats, ground	7	7
Corn meal	12	12
Bran and corn meal	14	14
Mixed feeds (bran and middlings)	56	33
Wheat offals (bran and middlings, unmixed)	76	69
Proprietary and mixed feeds (mostly corn and oat products)	177	123
Poultry foods	39	25
Miscellaneous feeds (oat hulls, screenings, etc.)	14	14
Total	518	353

In the feed inspection this year an unusually large number of samples of corn meal and corn and oat products were collected in order to discover if possible the extent of adulteration, if any, and, owing to the fact that the inspection covered so many samples, it was impossible to analyze them as soon as they reached the laboratory. When the time came to analyze them it was found that many were so moldy and wet that an analysis of such materials would not represent the composition of the samples as found in the market. The cause of the bad condition of these samples lies in the fact that the summer of 1902 was unusually wet and the cereals, especially corn, did not dry out properly but contained an excess of moisture. The presence of this abnormal content of moisture hastens the growth of certain molds which could be readily seen on the surface of the material and it has been shown[1] that samples analyzed after this mold

[1] N. J. Agrl. Expt. Stat. Bul. 160 (1902).

had formed contained much less fat and this loss in fat, amounting in some cases to 12 per ct. of the total, was undoubtedly due to the action of the mold. Therefore, sixteen samples of corn meal, nine of corn and oat chop, two of bran and corn meal, three of materials in which there was a large proportion of corn and one sample of rye grains, were not included in our examinations.

COMMENTS ON FACTS DISCLOSED BY THE INSPECTION OF 1903.

The inspection of concentrated feeding stuffs has for its main purpose such control of the feeding stuff trade that fraud shall be prevented and consumers shall be assured that all commercial feeds are sold in accordance with their real quality. To this end samples are taken, not only of licensed feeds to determine if their composition corresponds with the guarantees, but also of feeds like corn meal, corn and oats ground together and wheat offals, materials that when pure do not come within the provisions of the law, but which may be adulterated and are then subject to legal restrictions.

It is well that the inspection is conducted on such broad lines, for occasional cases of fraud are discovered that otherwise would not be brought to light. If the present tendencies towards adulteration of feeding stuffs continue, it may become necessary to place under supervision all ground grains and all offals from manufacturing processes of whatever character.

CHARACTER OF FEEDING STUFFS FOUND IN THE MARKET.

The most marked characteristic of the feeding stuff trade at the present time is the large and increasing sale of manufacturer's by-products, materials varying greatly in character and value. Most noteworthy and significant is the increase in the number of those feeds that are a mixture of two or more by-products, feeds that generally bear proprietary names and which in many cases are compounded for the purpose of disposing of some inferior material, that,

offered to the public without disguising it, could not be successfully floated on the market. A characteristic and not uncommon example of such feeds is a mixture of some corn product with oat hulls or of wheat bran with corn cobs, or similar material. Feed mixtures of this general type, that is, those containing several by-product ingredients, whether inferior or not, have increased from 41 licensed brands in 1900 to 78 licensed brands in 1903.

USE OF INFERIOR MATERIALS IN LICENSED BRANDS.

The use of inferior materials in licensed brands is, in a certain sense, legalized by the certificate issued by the Station, but these certificates are not a guarantee of good quality. They simply show that the law has been complied with as to the license fee and the registration of the guaranteed analysis; and are in no sense an endorsement, official or otherwise, of the feeds whose sale is thus legalized. Moreover, the Station cannot prevent the sale of inferior feeds, no matter how unfortunate this may be, when they are sold or offered for sale in accordance with the specified legal regulations. The chief purpose of the law is to secure for the purchaser information concerning what he buys, but no legislation whatever will defend the consumer against the results of his own ignorance or indifference, when he buys inferior articles about which he may gain information. To illustrate, several brands are licensed in New York that consist of wheat bran into which is introduced corn cobs or similar materials. To the uninitiated the mixture appears to be pure bran but the guarantee for protein shows that it is not. The intelligent, careful buyer is therefore not deceived, but the uninformed may be. The same is true of mixtures containing oat hulls. They are so compounded that the consumer who does not examine the goods and take into account the guarantees and all other facts, buys what he does not expect or care to buy.

The presence of inferior ingredients in a feed is generally indicated by the proportion of crude fiber present and in some cases by the low

proportion of protein. Making selection on this basis, the following samples of licensed feeds evidently contain oat hulls, corn cobs or some other adulterant, or perhaps very inferior grains.

TABLE IV.—BRANDS NEEDING SPECIAL CONSIDERATION.

No. sample.	Name of feed.	Protein.	Fat.	Fiber.
		Per ct.	*Per ct.*	*Per ct.*
784	Corn meal, from Montgomery Bros., Warsaw,	8.6	3.6	7.9
1071	" "	8.0	3.2	3.5
1070	Bran, wheat, from D. H. Grandin, Jamestown,	14.0	3.8	13.4
1072	" " " " " "	12.6	3.3	14.3
562	Mixed feed, Belmore,	12.8	3.7	13.9
1015	" " "	11.7	2.7	15.5
886	" " Jersey,	12.9	3.0	14.3
592	" " Blue Grass,	11.4	3.1	14.5
678	" " "	12.8	3.3	13.3
707	" " "	11.1	2.3	16.6
549	Corn and oat feed, Victor,	8.8	4.2	11.2
627	" " " " "	9.7	4.4	11.3
658	" " " " "	9.3	4.1	10.8
695	" " " " "	8.9	4.2	10.8
701	" " " " "	9.9	4.5	9.8
822	" " " " "	9.1	4.0	11.6
840	" " " " "	9.9	4.3	12.1
1028	" " " "	8.9	5.0	17.3
575	" " " " Boss,	9.4	5.0	11.7
777	" " " " "	8.4	4.1	13.3
970	" " " " "	7.3	2.9	17.5
590	" " " " Durham,	6.3	1.7	19.3
709	" " " " "	8.9	4.8	14.9
585	" " " " Ned,	9.4	5.1	13.7
622	" " " " "	8.9	5.0	13.2
724	" " " " "	9.3	5.4	15.6
1001	" " " " De-Fi,	10.1	3.3	15.5
537	" " " " Anchor,	9.2	3.1	11.4
858	" " " " "	9.4	2.6	13.2
676	Oat feed, Vim,	6.4	2.7	26.1
794	" " "	7.6	3.2	22.8
846	" " "	7.1	2.9	23.9
1064	" " "	6.8	2.6	25.4
1034	" " Standard,	7.6	3.0	24.5
677	" " Cream,	6.7	2.4	24.1
995	" " Royal,	6.3	2.2	25.9
591	Dairy feed, Daisy,	9.4	2.1	21.7
754	" " "	7.8	2.9	23.2
971	" " "	7.0	2.4	26.9

Special attention is called to the brands known as Belmore, Jersey and Blue Grass. These consist of adulterated bran. The proportion of inferior material present, ground corn cobs without question, as indicated by the percentage of crude fiber in excess of what it should be in pure bran, is estimated to be at least 15 per ct., or more than one-seventh of the total weight of the mixture. The diminished protein content, about 3½ per ct. less than that of pure bran, indicates adulteration to not less than the extent named. The price of these brands should therefore be at least one-seventh less than the price of pure bran, for no farmer can afford to pay anything for corn cobs.

The last ten samples shown in the above table, including the so-called oat feeds known as Vim, Standard, Cream and Royal and the Daisy Dairy Feed, are evidently largely oat hulls and consequently are of very inferior quality. These goods are sold at prices altogether too high in proportion to the cost of feeds of good quality.

The so-called corn and oat feeds, Victor, Boss, Durham, Ned, De-Fi and Anchor, while containing some corn and possibly a proportion of other ground grains, are also made up in part of oat hulls or other low grade materials and this fact should be taken into consideration by buyers. The Quaker and H.-O. Dairy Feeds carry more fiber than the average found in ground oats, and as some corn product is present which contains practically no fiber, the presence of by-products rich in crude fiber is fairly to be inferred. The above comments on the several feeds mentioned are made as a matter of justice to consumers.

FRAUDULENT AND ILLEGAL USE OF INFERIOR MATERIALS.

Occasionally unlicensed adulterated materials, sold as pure, are found in the market. Wheat bran and the ground grains should be carefully scrutinized with reference to the presence of corn cobs, oat hulls and other cheap stuff.

To illustrate, adulterated wheat bran was found on sale by D. H. Grandin at Jamestown, N. Y. (Sample 1072), but owing to an unex-

pected interpretation of the law, the offender is likely to escape direct punishment, although his fraudulent practices have been exposed to his neighbors and he has evidently ceased to offer the goods in question. Several samples of corn meal were found to be suspiciously low in protein and high in fiber. One sample demands special notice, viz., the one taken at the store of Montgomery Bros., Warsaw, said by the dealers to have been bought of the Diamond Mills, Buffalo. The protein is too low and the fiber four times too high for pure corn meal. In fact the composition corresponds closely to that of corn and cob meal and it was either such material or, what seems more probable, finely ground cobs or other inferior material was mixed with pure corn meal.

In two cases at least, information furnished to dealers on the basis of samples submitted, has either prevented the sale within the state of inferior cottonseed-meal or has forced a Memphis jobber to face a settlement in accordance with the quality of the material shipped. In other cases we have been able to advise dealers concerning goods not so good as represented.

THE ACTUAL COMPOSITION OF THE SAMPLES TAKEN AS COMPARED WITH THE GUARANTEES OF THE SEVERAL BRANDS.

The samples of cottonseed-meal and linseed meal show quite marked variations in the proportion of protein present, in some cases the percentages falling below, and in some instances exceeding, the guarantees.

Similar variations appear in the several gluten products and brewer's and distiller's wastes. It is probable that this unevenness of composition can hardly be avoided because of differences in manipulation as well as variations from year to year in the composition of the original grains that enter into the process of manufacture. Such variations, of the extent shown, do not necessarily indicate bad faith on the part of the manufacturer unless they are found to exist

uniformly in the same direction during successive years. It is not difficult, where feeds are inspected year after year, to determine when there is a deliberate purpose to place goods on the market that are inferior to the guarantees.

It should be said of the compounded feeds and hominy feeds that in almost all cases the actual proportions of protein and fat present were found to agree, within reasonable limits, with the guarantees. Numerous analyses of bran, middlings and of mixed wheat offals show that these feeds are, as rule, of good quality and unmixed with inferior materials.

Many samples of corn and oat feed were taken that were found to be true to name, that is, these were composed of whole corn and whole oats ground together.

VIOLATIONS OF THE LAW.

The traveling agents of the Station reported numerous instances of violation of the concentrated feeding stuff law, a very large proportion of which were offences of a minor character, due to negligence or ignorance, such as keeping in stock unlicensed mixtures of corn meal and wheat bran, failure of the dealer to have in his possession the statements required when licensed goods are sold in bulk, and the selling of mixed wheat offals under proprietary names with no markings on the bags or attached thereto to show the real character of the contents. These cases were in many instances satisfactorily adjusted by correspondence. Forty-eight cases were reported to the Commissioner of Agriculture, in nearly all of which compliance with the law was secured in accordance with the thirty day provision of Sec. 127. Some complaints are still pending.

It is proper in this connection to emphasize the fact that keeping in stock mixtures of corn meal and wheat bran, or any mixtures whatsoever other than those of the ground grains or of wheat offals, without the payment of a license fee and the filing of a guaranteed analysis, must be regarded as a violation of law.

It is entirely legal, of course, for dealers to sell the unmixed materials and then mix them at the request of the buyer. It is a great convenience to be able to keep mixtures in stock, and many not unnaturally regard it as a hardship that this is not allowed, but a little reflection makes it clear that to allow this would open an easy way for the practice of all sorts of adulteration and fraud.

The sale of "mixed feeds" (mixed wheat offals) under proprietary names merely has necessarily received attention. It is provided that the brans and middlings from wheat, rye and buckwheat may be sold without regard to the provisions of law applying to most other feeds, provided these are "sold separately as distinct articles of commerce." This provision has been construed as applying to mixed wheat offals when pure and when sold under names that characterize the real nature of the mixture.

CONDIMENTAL PREPARATIONS.

We have repeatedly called attention to the so-called condimental preparations found in the markets. These generally consist of some common feeding stuff like linseed meal as a basis, with which is mixed varying proportions of aromatic and other substances. As medicines these mixtures are regarded by veterinarians as without importance and as foods they have none of the remarkable properties claimed for them. They are worth for feeding purposes simply what the bran or oil meal or other feed present is worth. The sale which these "condimentals" now have, wholly because of skillful advertising, is a fact not very complimentary to the intelligence of farmers.

THE CHARACTER OF FEEDS IN GENERAL.

The freedom of comment in this bulletin on the low grade goods found in the markets should not lead readers to the conclusion that the great bulk of commercial feeding stuffs now offered to consumers are adulterated or of inferior quality.

The reverse is true, and buyers have everywhere abundant opportunity to purchase first class goods.

APPENDIX.

I. Periodicals Received by the Station.

II. Meteorological Records.

Appendix.

PERIODICALS RECEIVED BY THE STATION.

Acclimatation	Complimentary.
Acker und Gartenbau Zeitung	"
Agricultural Epitomist	"
Agricultural Gazette of New South Wales	"
Agricultural Journal and Mining Record (Natal)	"
Agricultural Journal of the Cape of Good Hope	"
Agricultural Ledger	"
Agricultural News	"
Allegan Gazette	"
American Agriculturist	Subscription.
American Chemical Journal	"
American Chemical Society, Journal	"
American Cultivator	Complimentary.
American Entomological Society, Transactions	Subscription
American Fancier	"
American Fertilizer	"
American Florist	"
American Gardening	"
American Grange Bulletin	Complimentary.
American Grocer	"
American Hay, Flour and Feed Journal	"
American Journal of Physiology	Subscription.
American Naturalist	"
American Philosophical Society, Proceedings	Complimentary.
American Poultry Journal	"
American Stock Keeper	"

Analyst	Subscription.
Annales de l'Institut Pasteur....................	"
Annals and Magazine and Natural History.......	"
Annals of Botany..........................	"
Archiv der gesammte Physiologie (Pflueger)....	"
Archiv fuer Hygiene........................	"
Association Belge des Chimistes, Bulletin.........	Complimentary.
Australian Garden and Field..................	"
Baltimore Weekly Sun......................	"
Beet Sugar Gazette.........................	"
Beiträge zur Chemischen Physiologie und Pathologie	Subscription.
Berichte der deutschen botanischen Gesellschaft..	"
Berichte der deutschen chemischen Gesellschaft...	"
Biochemisches Centralblatt	"
Biological Bulletin	"
Biologisches Centralblatt	"
Boletim da Agricultura......................	Complimentary.
Boston Society of Natural History, Proceedings..	Subscription.
Botanical Gazette	"
Botanische Zeitung	"
Botanisches Centralblatt	"
Botaniste, Le	"
Breeders' Gazette	"
Buffalo Society of Natural Sciences, Bulletin.....	Complimentary.
Bulletin of the Department of Agriculture, Jamaica	"
California Fruit Grower.....................	Subscription.
Campbell's Soil Culture.....................	Complimentary.
Canadian Entomologist	Subscription.
Canadian Horticulturist	Complimentary.
Cellule, La	Subscription.
Centralblatt fuer Agrikultur-Chemie............	"

Centralblatt fuer Bakteriologie und Parasitenkunde.	Subscription.
Chemical News	"
Chemical Society, Journal	"
Chemiker Zeitung	"
Chemisches Centralblatt	"
Chicago Daily Drovers' Journal	Complimentary.
Chicago Dairy Produce	"
Cincinnati Society of Natural History, Journal	"
Columbus Horticultural Society, Journal	"
Commercial Poultry	"
Country Gentleman	Subscription.
Country World	Complimentary.
Dairy and Creamery	"
Detroit Free Press	"
Elgin Dairy Report	"
Elisha Mitchell Scientific Society, Journal	"
English Catalogue of Books	"
Entomological News	Subscription.
Entomological Society of Washington, Proceedings	"
Entomologische Zeitschrift	"
Entomologist	"
Entomologists' Record	"
Fanciers' Review	Complimentary.
Farm and Fireside	"
Farm Journal	"
Farm Life	"
Farm News	"
Farm Poultry Semi-Monthly	"
Farm, Stock and Home	"
Farmers' Advocate	"
Farmers' Call	"
Farmers' Guide	"

Farmers' Sentinel	Complimentary.
Farmers' Tribune	"
Farmers' Voice	"
Feather	Subscription.
Feathered World	"
Floral Life	"
Florists' Exchange	"
Flour and Feed	Complimentary.
Fuehling's Landwirtschaftliche Zeitung	Subscription.
Garden	"
Gardeners' Chronicle	"
Gardening	"
Gartenwelt	"
Gleanings in Bee Culture	Complimentary.
Green's Fruit Grower	"
Hartwick Seminary Monthly	"
Hedwigia	Subscription.
Herd Register	Complimentary.
Hoard's Dairyman	"
Holstein-Friesian Register	"
Holstein-Friesian World	"
Homestead	"
Horticultural Visitor	"
Hygienische Rundschau	Subscription.
Indiana Farmer	Complimentary.
Insect World	"
Ithaca Democrat	"
Jahresbericht der Agrikultur-Chemie	Subscription.
Jahresbericht Gärungs-Organismen	"
Jahresbericht der Nahrungs und Genussmittel	"
Jahresbericht Pflanzenschutzes	"
Jersey Bulletin	Complimentary.

Journal of Applied Microscopy	Subscription.
Journal de Botanique	"
Journal of the Department of Agriculture of Western Australia	Complimentary.
Journal of Experimental Medicine	Subscription.
Journal fuer Landwirtschaft	"
Journal of Mycology	"
Journal of Physiology	"
Just's Botanischer Jahresbericht	"
Landwirtschaftlicher Jahrbuch	"
Landwirtschaftlicher Jahrbuch der Schweiz	"
Landwirtschaftlichen Versuchs-Stationen	"
Live Stock and Dairy Journal	Complimentary.
Milch Zeitung	Subscription.
Mirror and Farmer	Complimentary.
Monthly Weather Review	"
National Nurseryman	"
National Farmer and Stock Grower	"
National Stockman and Farmer	"
Naturaliste Canadienne	"
Nebraska Farmer	"
New England Farmer	"
New York Academy of Science, Annals and Transactions	Subscription.
New York Botanical Garden, Bulletin	Complimentary.
New York Entomological Society, Journal	Subscription.
New York Farmer	Complimentary.
New York Tribune Farmer	"
North American Horticulturist	"
Northwest Pacific Farmer	"
Oesterreichische Chemiker Zeitung	Subscription.
Ohio Farmer	Complimentary.

Ohio Poultry Journal	Subscription.
Pacific Coast Dairyman	"
Pacific Coast Fanciers' Monthly	"
Pacific Fruit World	Complimentary.
Pacific Rural Press	Subscription.
Photo-Miniature	"
Photographic Times-Bulletin	"
Popular Agriculturist	Complimentary.
Poultry Herald	Subscription.
Poultry Keeper	Complimentary.
Poultry Industry	"
Poultry Monthly	"
Practical Poultryman and Poultry Star	"
Practical Farmer	"
Practical Fruit-Grower	"
Praktische Blätter fuer Pflanzenschutz	Subscription.
Psyche	"
Queensland Agricultural Journal	Complimentary.
Reliable Poultry Journal	"
Republic	"
Revue Generale de Botanique	Subscription.
Revue Horticole	"
Revue Mycologique	"
Royal Agricultural Society, Journal	"
Royal Horticultural Society Journal	Complimentary.
Rural New Yorker	Subscription.
Salt Lake Herald	Complimentary.
Saint Louis Academy of Science, Transactions	"
Sanitary Inspector	"
Science	Subscription.
Scientific Roll	"
Society of Chemical Industry, Journal	"

Societe Entomologique de France, Bulletin.......	Complimentary.
Societe Mycologique de France, Bulletin.........	Subscription.
Southern Planter	Complimentary.
Southern Farm Magazine.....................	"
Southwestern Farmer and American Horticulturist	"
Station, Farm and Dairy......................	"
Stazione Sperimentale Agrarie Italiane..........	"
Strawberry Specialist	"
Sugar Beet	"
Texas Stockman and Farmer..................	"
Torrey Botanical Club, Bulletins and Memoirs...	Subscription.
Transvaal Agricultural Journal.................	Complimentary.
Up-to-Date Farming and Gardening............	"
Utica Semi-Weekly Press.....................	"
Wallace's Farmer	"
West Indian Bulletin.........................	"
West Virginia Farm Review..................	"
Western Fruit-Grower	"
Western Plowman	"
Woman's Home Companion..................	"
Zeitschrift fuer Analytische Chemie...........	Subscription.
Zeitschrift fuer Biologie.......................	"
Zeitschrift fuer Fleisch und Milch Hygiene......	"
Zeitschrift fuer Pflanzenkrankheiten............	"
Zeitschrift fuer Physiologische Chemie..........	"
Zeitschrift fuer Untersuchung der Nahrungs und Genussmittel	"
Zoologischer Anzeiger	"
Zoological Record	"

METEOROLOGICAL RECORDS FOR 1903.

PRECIPITATION BY MONTHS SINCE 1882.

YEARS.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
1882	....	....	....	....	....	3.69	2.42	2.37	1.25	0.62	1.22	0.55	.....
1883	0.48	1.44	0.88	1.58	4.45	4.12	2.98	3.47	2.12	2.10	1.54	0.73	25.89
1884	1.83	2.01	2.54	0.83	2.49	2.01	2.33	1.44	3.17	1.67	1.01	0.97	22.30
1885	1.07	0.61	0.12	1.26	1.58	2.49	4.64	5.02	2.11	2.88	1.36	0.76	23.90
1886	1.13	0.95	1.13	4.13	1.92	2.92	4.41	2.86	2.31	1.39	3.48	1.24	27.87
1887	0.18	2.17	0.48	1.37	0.46	2.01	6.37	3.03	0.75	1.74	1.58	1.35	22.29
1888	0.78	1.04	1.43	3.09	2.79	3.88	0.99+	4.02	2.73	3.47	2.02	1.24+	27.48
1889	2.99+	0.25	0.66+	3.28	1.21	7.47	4.57	4.98	2.50	3.32	3.44	1.62	32.28
1890	2.16	1.45	2.16	2.20	5.49	5.26	1.07	4.34	5.81	4.54	2.40	....	36.88
1891	1.44	1.57	3.25	1.63	0.49	4.31	3.52	3.16	0.47	3.65	0.74	3.29	27.52
1892	0.57	0.88	0.55	0.67	4.04	3.95	1.89	4.77	1.12	1.34	2.67	0.72	23.17
1893	1.62	3.71	1.94	2.59	4.92	3.08	3.68	5.38	2.68	1.59	1.09	1.56	33.84
1894	2.21	2.71	1.36	2.43	7.03	1.77	1.50	1.22	4.64	3.59	0.43	0.47	29.36
1895	0.96	....	0.29	1.33	2.88	....	....	2.66	0.94	0.72	2.31	2.49	.....
1896	1.19	2.28	0.84	0.41	2.31	3.71	4.12	3.33	4.27	2.26	2.18	0.71	27.61
1897	0.64	0.21	2.12	1.90	2.19	3.16	5.28	1.27	2.36	0.73	2.53	1.39	23.78
1898	1.74	0.83	1.54	2.03	1.90	2.39	1.32	3.60	1.86	3.83	2.03	0.33	22.90
1899	0.37	0.30	1.22	1.12	1.69	1.71	4.15	1.05	2.23	2.69	1.36	1.46	19.35
1900	1.43	2.42	0.02	0.95	1.71	1.45	6.53	1.75	0.91	3.65	6.13	0.78	27.73
1901	0.72	....	2.19	4.43	3.80	2.07	3.97	5.62	2.46	1.35	2.09	3.37	32.07
1902	0.86	0.66	1.94	1.92	2.84	4.33	5.25	2.41	2.88	2.32	0.74	0.74	26.89
1903	1.81	1.11	5.60	2.60	0.23	7.77	4.86	7.21	1.30	4.19	1.63	0.38	38.69

READINGS OF THE STANDARD AIR THERMOMETER.

DATE.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 p. m.	12 m.	5 p. m.
1	24.	43.	39.	33.	39.	37.	21.	21.	21.	36.	44.	48.	32.5	40.	40.5	52.	71.	69.
2	21.	36.	36.	38.	39.	44.5	27.	34.	33.	45.	59.	56.	35.	50.	57.	59.	77.	78.5
3	37.	41.	39.	34.	38.5	37.	29.	42.	45.	56.	47.	40.	44.	58.	53.	63.	82.	82.5
4	32.	35.	32.	40.	50.	42.5	36.	40.	39.	25.	25.	26.	43.	50.	53.	57.5	75.	73.
5	29.	32.	28.	20.	20.	26.	33.5	40.	41.	24.	31.	35.5	39.	60.	60.	51.	72.5	71.
6	24.	26.	24.	25.	31.	29.	30.	37.	41.	32.	49.	47.	47.	65.5	69.	59.	74.	79.5
7	23.	26.	28.	22.5	28.	25.	38.5	45.	44.	46.5	51.	57.	50.5	57.	50.	61.	73.	68.
8	17.5	19.	13.	30.	32.	33.	43.	47.	41.	43.	52.	47.5	50.	66.	67.	66.	70.	70.5
9	—2.	15.	15.	25.	30.	30.5	35.	43.5	46.	40.	51.	55.	51.	76.5	77.5	64.	81.	66.
10	15.	14.	15.	26.	43.	45.	41.	46.	48.	41.	48.	48.	63.	79.	76.	65.	66.	64.
11	15.	25.	30.	38.	39.	40.	39.	41.	46.	37.	47.	49.	58.	75.	77.	57.	65.	59.
12	13.	13.	10.	37.	38.5	40.	40.	44.	47.	44.	53.	55.	55.	75.	78.	51.	51.	52.
13	11.	14.	13.	34.	35.5	33.	36.	41.	48.	41.	56.	55.5	54.	75.5	80.	54.	60.	64.
14	15.	21.	21.	21.	21.	20.	30.	52.	48.	43.	44.	45.	55.	68.	58.	52.	52.5	54.
15	25.	30.	32.	18.	25.	24.	34.	44.	43.	41.	43.	43.	51.	71.	71.	53.	65.	71.
16	33.	35.	35.	18.	21.	17.	39.	45.	43.	41.	42.	42.	55.	76.	79.	62.	72.5	71.
17	37.	36.	32.	7.	6.	4.	40.	50.	54.5	35.	42.5	50.	59.5	83.	82.5	60.	57.	61.
18	11.	10.	9.	—4.	10.	8.	45.	63.	68.	40.	46.	49.	64.	82.	83.	54.	65.	63.
19	5.	12.	10.	—1.	11.	14.	53.	65.	75.	38.	51.	54.	65.	87.5	85.	58.	66.	70.
20	12.	26.	29.	6.	19.	20.	52.	71.	71.	39.	51.	48.	71.5	82.5	79.5	56.	68.	62.
21	32.	33.	33.	18.5	30.	29.	56.	61.	45.	36.	41.	36.	65.	83.	85.	57.	66.	69.5
22	28.	28.	28.	19.	24.	25.5	32.5	43.5	46.	36.	44.	42.	68.	71.	70.	60.5	70.	71.5
23	28.	20.	15.	23.	39.	37.	40.	42.5	49.	39.	49.	48.	56.	63.	61.	55.	59.	61.
24	3.	13.	15.	29.	30.	27.5	42.	33.	37.5	35.	56.	50.	50.	55.5	62.	58.	67.	64.
25	18.	24.	24.	23.	33.	35.	35.	35.	35.	39.	50.	49.	52.	69.	72.5	62.	65.	65.5
26	24.	31.	34.	27.	40.	45.	33.5	46.	54.5	38.	55.	53.	57.	61.	62.5	62.	72.	75.
27	30.	37.	37.	30.	43.	43.	51.	48.	41.	43.	61.	64.	60.	75.5	73.	61.	71.	68.
28	36.	41.	40.	49.	62.	44.	33.	34.	39.	47.	70.	75.	67.	76.	75.	57.	68.	74.
29	40.	42.	44.	.....	.....	.....	30.	37.	41.	65.	76.5	77.	49.	55.5	60.	63.	65.	69.
30	37.	29.	23.	.....	.....	.....	33.	41.	41.	61.	83.	80.	48.	60.	58.	63.	80.	84.
31	19.	24.	31.	.....	.....	.....	38.	50.	56.	.....	.....	.....	48.	63.	63.	.....	.....	.....
Average	22.4	26.8	26.3	24.7	31.3	30.6	37.6	44.6	46.	40.9	50.6	50.8	53.7	68.1	70.6	58.4	68.2	68.4

READINGS OF STANDARD AIR THERMOMETERS—(*Concluded*).

DATE.	July.			August.			September.			October.			November.			December.		
	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.	7 a. m.	12 m.	5 p. m.
1	76.	85.	89.5	60.	71.	71.5	60.	69.	69.	58.	67.	66.	44.	58.	53.5	19.	30.	32.
2	76.	83.5	83.5	61.	74.	74.	58.5	73.	74.	57.	57.	59.	39.	63.	57.	22.	32.	26.
3	71.	74.	75.	62.	75.	73.	61.	80.	81.	51.	68.	66.	49.	65.	62.	22.	25.	29.
4	69.5	76.	76.	64.	62.	63.	65.5	85.5	82.	58.	68.	65.5	46.	67.	60.	21.	33.	32.
5	69.	75.	75.	59.	65.5	68.5	60.	69.	61.	62.	67.	69.	52.	37.	36.	28.	28.	25.
6	66.	78.5	81.	64.	72.	67.	52.	66.	64.	49.	64.	65.	29.	34.	30.	29.	32.	31.
7	68.	81.	83.	56.	63.	64.	54.	64.	60.	63.	69.	69.	30.	32.	32.	25.	31.5	34.
8	70.	85.5	90.	52.	67.	70.	55.	63.	60.	56.	50.	52.	30.	46.	45.	28.	27.	26.
9	76.	90.	91.	62.	70.5	73.5	61.	73.	71.	50.	52.5	50.	35.	54.	51.	26.	31.	28.
10	79.	83.	88.5	59.	70.	75.5	68.	81.	81.	47.	50.	49.	40.	60.	46.	24.	25.5	25.
11	72.	70.	80.	66.	79.	72.	60.	71.	73.	46.	52.	51.	35.	47.5	50.	23.	28.5	24.
12	71.	76.	71.	59.	60.	65.	60.	76.	80.	48.	52.	53.	39.	48.	44.	23.	25.	33.
13	62.	72.	70.	55.5	68.	69.	72.	85.	86.	48.	60.	58.5	38.	47.	43.	30.	24.	17.
14	59.	65.	66.	57.	71.	75.	70.	83.	85.5	49.	58.	56.	35.	45.	38.	7.	14.	13.
15	53.	59.	62.	58.	75.	74.	69.	84.	82.	47.	57.	59.	31.	41.	38.	12.	14.5	13.
16	62.	73.	66.5	65.	76.	76.	70.	78.	80.	53.5	67.	63.	35.	42.	47.	17.	23.	21.
17	65.	75.	75.	60.	76.	79.	68.	75.	63.	55.	58.5	56.	44.	41.	38.	21.	26.	27.
18	63.5	65.	61.	62.	79.5	85.	47.	58.	58.5	43.	44.	44.5	25.	27.	26.	13.	11.	7.
19	61.	67.	74.	68.	81.	68.	45.	63.	62.	44.	55.	58.	24.	25.	25.	14.	23.	28.
20	65.	73.	64.	63.	74.5	76.	50.	65.	68.	53.	59.5	54.	21.5	30.	24.	35.	39.	39.
21	65.	75.	80.	60.	72.	78.	51.	72.5	75.	46.	54.	50.	19.5	32.	30.	31.	37.	38.
22	65.	69.	70.	73.	81.	79.	59.	72.	74.	42.	63.	60.	30.	32.5	34.	27.	20.	17.
23	64.	71.	78.	64.	74.5	75.5	56.	78.	79.	45.	48.	43.	33.	36.	41.	23.	39.	39.
24	69.	76.	77.	62.	75.	71.5	47.	54.	52.	35.	41.	37.	31.	30.	24.	35.	37.	40.
25	69.	85.	87.	66.	83.	74.	45.	60.	61.	32.	48.5	51.	18.	21.	16.5	30.	26.	25.
26	75.	69.5	75.	59.5	69.	66.	52.	73.	72.5	33.	34.	37.	19.	18.5	12.	11.	6.	2.
27	59.	67.	68.	55.	65.	65.	63.	61.	62.	29.	37.	35.	19.	23.5	20.	9.	17.	21.
28	56.	70.	70.	58.	62.	59.	46.	51.5	48.	33.5	43.	40.	23.	26.	22.5	8.	9.	7.
29	66.	74.	83.5	56.	57.	59.	39.	55.	57.	46.	61.	60.	21.	29.	24.	13.	22.5	25.
30	70.	75.	82.	58.	60.	63.	44.	65.	71.5	54.	63.	58.	22.	28.	27.	20.	20.	17.
31	58.	64.	67.	60.	68.	69.	....	....	....	46.	64.	59.	....	....	....	18.	25.	22.
Average	66.8	74.3	76.1	60.8	70.9	70.9	56.9	70.1	69.8	47.7	55.9	54.6	31.9	39.5	36.5	21.4	25.2	24.6

READING OF MAXIMUM AND MINIMUM THERMOMETERS.

1903.	JANUARY.		FEBRUARY.		MARCH.		APRIL.		MAY.		JUNE.	
	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.
1.......	48.	22.	40.	22.	45.	19.	56.	34.	80.	30.	76.	39.
2.......	39.	18.	46.	35.	35.	19.	62.	36.	52.	24.	80.	43.
3.......	48.	33.5	51.	33.5	47.	28.	60.	40.	63.	38.	85.	45.
4.......	40.	31.	53.	32.	45.	33.	41.	23.	55.	41.	82.5	51.
5.......	33.	27.	43.	7.5	45.5	30.	37.	21.	65.	31.	77.	41.
6.......	28.5	23.	33.	21.	42.	29.	51.	24.	73.	34.	82.	56.
7.......	28.	15.	30.	21.	49.	25.	61.	42.	70.	45.	79.5	58.
8.......	33.	13.	35.5	18.	47.	40.	57.	37.5	71.	43.	78.	60.
9.......	17.	—2.	34.	10.	46.	34.	57.	35.	80.	40.5	85.	56.
10.......	18.	12.	49.5	25.	49.	40.	57.	37.	81.	49.5	72.	59.
11.......	30.5	10.	45.	34.	49.	37.	52.	32.5	81.	50.	68.	52.
12.......	35.	10.	44.	30.	48.	39.	59.	40.	82.	44.	59.	50.
13.......	16.	8.	41.	33.	50.	35.	60.	37.	81.	49.	66.	51.
14.......	22.	10.	34.	19.	57.	28.	56.	42.	80.	52.	64.	49.
15.......	33.	20.	26.	16.	52.	33.	45.	40.	74.5	45	71.	51.
16.......	39.	29.	21.	16.	46.	30.	45.	40.	80.	42.	76.5	56.5
17.......	40.	30.	17.	4.	57.	39.	51.	33.	85.	57.	73.	55.5
18.......	33.	9.	13.	—4.	71.	43.	51.	39.	88.	54.	67.	47.
19.......	14.5	1.	15.	—2.	78.5	45.	55.	33.	89.	55.	73.	51.
20.......	30.5	8.	23.	0.	77.	50.	54.	33.5	86.	63.	70.	52.
21.......	33.5	27.	35.	6.	71.	44.	49.	31.	87.	51.	71.	56.
22.......	33.	27.	30.	17.	46.	32.	46.	32.	80.	64.	75.	49.
23.......	33.	15.	42.	15.	49.	38.	50.	38.	71.	43.5	71.5	54.
24.......	17.	3.	37.	27.	49.	32.	58.	30.	63.	46.	70.	53.
25.......	26.	15.	35.	22.	39.	31.	52.	37.	74.	38.	68.	54.
26.......	37.	23.	46.	20.	54.5	32.	60.	28.	72.5	52.	77.	51.
27.......	39.	29.	45.	29.	54.5	41.	66.	33.	79.	55.	75.	56.
28.......	44.	34.	62.5	39.	42.	32.5	75.	37.	80.	58.	75.	47.5
29.......	45.	36.	...	...	42.	23.	80.5	48.	75.	41.	74.	60.
30.......	46.	23.	...	...	42.5	26.	86.	50.	62.	45.	86.5	58.
31.......	31.	19.	...	...	57.	35.	...	...	65.	35.	...	...
Average.	32.6	18.7	36.7	19.7	51.1	33.6	56.3	35.4	75.	45.7	74.3	52.1

READING OF MAXIMUM AND MINIMUM THERMOMETERS—(*Concluded*).

1903.	JULY.		AUGUST.		SEPTEMBER.		OCTOBER.		NOVEMBER.		DECEMBER.	
	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.	5 p. m. Max.	5 p. m. Min.
1.......	90.	67.	76.5	52.	77.	57.	73.	53.	60.	40.	38.	17.
2.......	90.	73.	76.	46.	80.	56.	66.	54.	64.	38.	32.	21.
3.......	84.	59.	78.	57.	83.	55.	69.	45.	68.	46.	34.	13.
4.......	81.	59.	73.	61.	89.	61.	71.	55.	70.	44.	37.	20.
5.......	80.	59.	69.	58.	82.	59.	72.	60.5	61.	35.	37.	20.
6.......	81.	62.	77.	61.	68.	46.	69.5	47.	36.5	27.	33.5	23.
7.......	85.	62.	68.5	55.	66.	49.	72.5	61.5	34.5	27.	34.	22.
8.......	90.	60.5	71.5	45.	64.5	49.	69.	49.	51.	28.	34.	25.
9.......	94.	64.	74.	61.	76.	58.	52.5	48.	58.	34.	31.	21.5
10.......	92.5	72.	78.	51.5	85.	64.	51.	47.	60.	38.	28.	22.
11.......	88.5	63.	81.	60.	82.	58.	57.	45.	54.	34.	29.	17.
12.......	81.	61.5	72.	56.	82.5	52.	56.	46.	51.5	32.	34.	21.
13.......	74.	56.	71.	49.	88.	66.	64.	46.	48.	35.	40.	17.
14.......	71.	52.	78.	45.	90.	65.	60.5	45.	45.	34.	18.	5.
15.......	68.	50.	78.	50.	87.5	65.	62.	40.5	41.	29.	15.5	12.
16.......	75.5	55.	79.5	54.5	83.5	65.	67.	52.	47.	33.	23.	12.
17.......	78.5	54.	80.	52.	80.	62.	63.	50.	54.	37.	29.	12.
18.......	76.	66.	85.5	55.	63.	43.	56.	41.	38.	23.	16.	7.
19.......	76.	58.	85.	62.5	67.	40.	62.	41.	29.	22.	31.	—4.
20.......	77.	60.	77.5	62.	70.	42.	64.	45.	32.	17.5	41.	25.
21.......	80.	58.	79.	54.	78.	44.	55.5	38.	34.	18.	39.	28.
22.......	81.	63.	83.	62.5	78.	57.	67.	34.5	34.	28.	39.	17.
23.......	78.	62.5	79.	60.	83.	51.	61.	42.5	41.	30.	40.	11.
24.......	79.	64.	78.	60.	79.	46.	43.5	33.	41.	23.	40.	32.
25.......	88.5	57.	85.	59.	64.	41.	52.	28.	24.	16.5	40.	24.
26......	87.	66.5	74.	58.	80.	48.	52.	31.	20.5	12.	25.	2.
27.......	70.	54.	67.	52.	72.5	59.	37.	28.	23.5	12.	24.	1.
28.......	73.5	46.	66.	56.	62.	43.	46.5	33.	32.	19.	21.	7.
29.......	84.	64.	59.	55.	59.	35.	65.	33.	31.	20.5	25.	7.
30.	84.	69.	65.	56.	73.5	38.5	66.	52.	33.	18.	21.	14.
31.......	82.	54.	72.	59.	...	...	70.	41.	...	...	25.	15.
Average.	81.3	60.4	75.4	55.6	76.4	52.5	61.	44.	43.9	28.4	30.8	15.8

SUMMARY OF MAXIMUM, MINIMUM AND STANDARD AIR THERMOMETERS FOR 1903.

	Maximum.	Minimum.	Standard.		
			7 a. m.	12 m.	5 p. m.
	Average.	Average.	Average.	Average.	Average.
January	32.6	18.7	22.3	26.8	26.3
February	36.7	19.5	24.5	31.3	30.6
March	51.1	33.6	37.6	44.6	46.
April	56.3	35.4	40.9	50.6	50.8
May	75.	45.7	53.7	68.1	70.6
June	74.3	52.1	58.4	68.2	68.5
July	81.3	60.4	66.8	74.3	76.1
August	75.4	55.6	60.8	70.9	70.9
September	76.4	52.5	56.9	70.1	69.8
October	61.0	44.0	47.7	55.9	54.6
November	43.9	28.4	31.9	39.5	36.5
December	30.8	15.8	21.4	25.2	24.6

AVERAGE MONTHLY TEMPERATURE SINCE 1882.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1883	17.4	22.3	23.6	43.3	52.0	66.6	67.4	65.6	56.3	46.6	39.1	27.5
1884	17.6	28.3	29.5	40.7	54.3	67.1	66.5	69.9	65.2	50.5	36.5	27.2
1885	20.6	11.4	18.8	41.2	54.3	63.6	69.7	65.0	58.3	49.2	39.3	27.8
1886	19.6	22.9	30.2	48.1	55.7	64.0	68.0	67.5	61.8	49.6	36.8	22.2
1887	20.2	23.2	26.3	41.1	62.5	65.7	75.6	66.5	57.7	47.0	37.6	27.6
1888	16.4	22.8	24.6	40.8	54.3	66.5	66.8	68.0	62.2	43.9	39.4	29.3
1889	29.1	18.1	33.9	45.1	58.4	65.3	70.2	66.0	60.5	44.0	40.3	35.2
1890	31.2	30.9	28.8	44.2	52.3	67.1	69.5	67.7	60.1	49.3	37.6	21.4
1891	25.9	28.3	30.8	45.3	52.0	66.4	66.4	68.5	66.2	48.3	38.4	35.5
1892	21.4	25.9	26.5	43.5	52.8	68.6	70.2	69.4	61.3	50.0	35.9	25.2
1893	15.5	20.6	29.5	41.1	54.1	68.2	69.8	68.8	58.0	52.0	38.2	27.5
1894	29.7	20.9	38.9	44.1	55.5	67.8	74.2	66.8	64.8	52.7	36.0	31.5
1895	21.8	16.9	26.9	44.4	59.0	....	....	71.2	61.7	45.4	39.6	31.4
1896	22.4	24.1	24.4	49.3	62.0	65 9	71.4	70.0	60.2	56.5	42.9	27.1
1897	23.2	26.1	33.8	45.0	55.4	62.3	73.6	67.6	62.3	52.6	39.7	29.2
1898	26.2	26.8	....	43.2	57.0	67.7	74.2	71.0	65.9	52.1	37.9	27.9
1899	22.1	20.4	30.4	46.6	57.6	69.5	71.2	71.6	60.6	53.4	38.9	30.0
1900	26.0	22.6	23.6	43.5	56.7	68.4	72.6	74.1	66.1	57.9	41.1	28.7
1901	26.1	18.5	32.2	46.5	56.9	68.9	76.6	71.0	64.0	51.4	34.3	27.7
1902	23.2	22.2	39.5	46.6	56.1	63.2	71.2	67.6	63.6	43.1	46.3	25.7
1903	25.7	28.1	42.4	45.9	60.4	63.2	70.8	65.5	64.4	52.5	36.2	23.3

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